PROCEEDINGS OF ABSTRACTS

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1. SESSION BIOENGINEERING

A14. Study of Development of Underfloor Material that Reduces Risk of Femur Fractures Due to Falls - Investigation of Relationship Between Load on Femur and Hardness and Thickness of Underfloor Materials

Takuya YAMASHITA¹, Yasumi ITO², Ryuichi YAMADA²
Sonoka OKURA¹, Yoshiyuki KAGIYAMA², Tetsuya NEMOTO³
¹Integrated Graduate School of Medicine, Engineering, and Agricultural Sciences, University of Yamanashi, Japan
²Graduate Faculty of Interdisciplinary Research, University of Yamanashi, Japan
³National Center for Geriatrics and Gerontology, Japan
E-mail: g20tm026@yamanashi.ac.jp

In Japan, the decline in walking function due to fall fractures in the elderly and the increase in the number of bedridden elderlies are social issues. In 2019, the causes of nursing care for the elderly were due to diseases from the first place to the third place, while the fourth place was "fall and fracture" at a rate of 12.5% of the total. Since this could be prevented by physical measures, we focused on safety flooring.

In order to reduce the load that bone is exposed to during a fall to the floor, three influence factors are involved: "pressure dispersion" of the surface flooring material, "energy absorption" and "action time" of the underfloor material. Our study revealed that laminated flooring, which combines hard surface flooring with soft cushioned underfloor materials, reduced impact load and reduces fracture risk by dispersing the impact of bone during a fall. It has been suggested that the decrease in impact load was due to the impact dispersion effect due to the bending rigidity of the flooring material and the shock absorption effect of the flooring material. Since the impact dispersion range increased as the bending rigidity of the flooring material increased, it has become clear that it is necessary to use an underfloor material which has lower hardness as the impact dispersion range increases. Further, since the shock absorption capacity differs depending on the hardness of the underfloor material, it is clear that it is necessary to consider the shock absorption ability due to hardness when selecting the underfloor material. It also has been suggested that the thickness of the underfloor material is effective for further reduction of impact load, however, the effect has not been measured.

Therefore, in this study, we investigated the effect of the thickness of flooring materials on shock absorption using laminated flooring materials in which the same flooring materials were combined with underfloor with different thicknesses. As a result, it was clarified that when a medium hardness underfloor material of 7 mm was used, it showed better buffering performance than when an 8 mm high hardness underfloor material was used.

From this study, it became clear that fractures could be reduced with considering the balance between surface flooring material and underfloor material, even if the thickness of the underfloor material is small.

A15. Study for the Effects of Material and Tip Shape on Straight-Line Stability of Needle Tips - Development of Minimally Invasive Needles for Gold Marker Implantation in Radiotherapy

Kohei OBATA¹, Yasumi ITO², Ryuichi YAMADA², Yoshiyuki KAGIYAMA², Masahide SAITO³, Hiroshi ONISHI³
¹Integrated Graduate School of Medicine, Engineering, and Agricultural Sciences, University of Yamanashi, Japan
²Graduate Faculty of Interdisciplinary Research, University of Yamanashi, Japan
³Department of Radiology, University of Yamanashi, Japan
E-mail: g20tm005@yamanashi.ac.jp
In the field of radiotherapy for cancer treatment, high-precision radiotherapy has attracted attention in recent years. In this radiotherapy, a gold marker implanted in the body of a patient is used for real-time tracking in order to reduce the area to be irradiated. As a pre-treatment, an indwelling needle is required for the gold marker implantation, and it is desirable to use the thinnest needle size to minimize damage to the surrounding tissue during puncture. However, low straight-line stability and deflection is often caused by the thinnest needle size and it becomes difficult to implant the gold marker relative to the target position. Therefore, a minimally invasive needle that has straight-line stability is considered to be ideal.

In this study, we investigated how the material and tip shape of the needle affect the straight-line stability of the needle, with the aim of developing a needle that is minimally invasive and straight-line stability. Firstly, we investigated the use of biomimetic materials as materials for evaluating the straight-line stability of the needle. Since the evaluation of soft tissue with heterogeneity is complicated, we investigated the possibility of simulating soft tissue using homogeneous materials such as the Hitohada gel and gelatin gel. As a result of comparing the puncture loads of porcine soft tissue and homogeneous materials, it was found that gelatin gel could simulate different biological sites by adjusting the internal temperature.

Therefore, secondly, we fabricated several needles with different materials and tip shapes and measured the deflection inside the gel by puncturing the gelatin gel. The materials used were stainless steel and tungsten, and the tip shape was varied from an angle of 10° to 60°. As a result, the deflection of stainless steel and tungsten was reduced by about 30%, indicating that the straight-line stability can be improved by using highly rigid materials. It was confirmed that the difference in material and tip shape affected the straight-line stability.

**A40. Establishment of in Vivo Method for Quantitative Evaluation of Whole-body Skin Viscoelasticity**

Ryuichi YAMADA¹, Yasumi ITO¹, Yuto SATO², Kohei OBATA², Kazuki KAMIUNTEN², Yoshiyuki KAGIYAMA¹ and Tetsuya NEMOTO¹,³

¹ Graduate Faculty of Interdisciplinary Research, University of Yamanashi, Japan
² Integrated Graduate School of Medicine, Engineering, and Agricultural Sciences, University of Yamanashi, Japan
³ National Center for Geriatrics and Gerontology, Japan

E-mail: ryamada@yamanashi.ac.jp

At present, the quantitative evaluation of the mechanical properties of the human body becomes important in the medical and nursing care field of Japan, which is a super-aging society. It is necessary to clarify the overall material properties of skin soft tissue which becomes a complex layered structure for prevention and countermeasure of pressure ulcer caused by positional immobilization in prolonged surgery and bedridden conditions. Each layer of the skin, such as epidermis, dermis, fat, and muscle, is not uniform, and are anisotropic and frequency-dependent, making it difficult to consider in in vitro measurements. Therefore, it is desirable to perform in vivo measurements on the actual human body.

Previous studies have found that the viscoelastic properties of the human arms, as measured by in vivo using rheometers, vary greatly with age-and gender. The rheometer has a measurement site restricted to the human arm, whereas the site of pressure ulcer development is systemic. From this point of view, we focused on the cutometer, which is used for viscoelastic measurement of the face and other parts in the cosmetic field and can measure the whole body. Then, the viscoelastic tendency of human arm and biomimetic materials by rheometer and cutometer was compared, and the development of simple and quantitative mechanical properties technique of the whole-body was tried.
Viscoelasticity measurements were carried out on human arms of men in their 20s and biomimetic materials made from urethane resin, gelatin, and silicone rubber. Both instruments showed the most elastic properties of biomimetic materials made of gelatin and silicone rubber. Higher correlations were observed for the rheometer loss tangent $\tan \delta$ (loss elastic modulus $G''$ / storage elastic modulus $G'$) with the viscosity index $R6 \left( \frac{Uv}{Ue} \right)$ and skin elasticity index $R7 \left( \frac{Ur}{Uf} \right)$ of the cutometer with correlation coefficient $r = 0.7$ or higher. The correlation coefficient with $R6$ increased to $r = 0.94$ when the value of the $\tan \delta$ of the rheometer was set to the $\tan \delta$ of 2 Hz instead of the average value of the frequency 0.5 to 2 Hz because the suction time of the cutometer was 2 seconds. The correlation between $R6$ and $\tan \delta$ was shown to become stronger as the values of rheometer frequency and cutometer suction time became closer. This suggests that matching the strain rates of both instruments would allow us to estimate $\tan \delta$ measured by rheometer from $R6$ and $R7$ measured by cutometer.

A42. Relationship between the Dislocation Moments and the Inset Heights of the Acetabular Cup of an Artificial Hip Joint with the Structure to Prevent Dislocation

Yuki KAWAMURA1, Mitushi OHMASA1 and Ei YAMAMOTO1
1Faculty of Biology-Oriented Science and Technology, Kindai University, Japan
E-mail: y-kawamura@waka.kindai.ac.jp

The number of surgeries for osteoarthritis (OA) is shown as increasing tendency. One of the effective treatments of OA is total hip arthroplasty (THA) used for artificial hip joints. It consists of two parts which are a femoral head and an acetabular cup. Moreover, the acetabular cup is constructed from an inner liner and an outer shell. In THA, there have been several problems such as the joint wear, loosening, and dislocation. The dislocation which is defined as the complete separation between the femoral head and acetabular cup is one of crucial postoperative complications of THA. We have newly proposed an artificial hip joint with the structure for preventing dislocation. The feature of this structure to prevent dislocation is that the femoral head is partially covered with the acetabular cup over hemi-sphere line. The dislocation does not easily occur due to this structure. Clinically, excessive rotational moments as well as pull-out forces cause dislocation after the surgery. In the present study, relationships between the dislocation moments and the inset heights of the acetabular cup were determined using finite element (FE) analysis. The FE model of 6.0 mm in the diameter of the femoral head was created using a commercial FE software (ANSYS Workbench 19.1). The inset height of the model was set at 0.5, 1.0, and 1.5 mm. For the analytical conditions, the outer surface of the outer shell was fully fixed and the rotational displacement was applied to the femoral head until dislocation occurred (Fig. 1). The dislocation moment was 35, 192, and 479 N·mm in case of 0.5, 1.0, and 1.5 mm inset height, respectively. The relationship between the dislocation moments and inset heights was fitted by the power function ($R2=0.999$) as shown in Fig. 1. The result of this study is useful to design an optimal structure of the artificial hip joint to prevent dislocation.

Key words: Artificial hip joint, Dislocation moment, Optimal design, Finite element analysis.
Elastin and collagen are typical of biological polymeric fibers in the extracellular matrix. They play important roles as major structural components to determine the morphology and function of biological soft tissues. High purity collagen can be isolated and purified from the tissues. Thus, there have been many scientific investigations on the collagen. In contrast, the pure molecular solution of elastin is hardly extracted due to its insolubility. From this reason, many basic characteristics of elastin have not been fully elucidated not only in the area of biochemistry and molecular biology but also in that of biomechanics. The normal function and disease state of various tissues are closely related to the elastin ingredients. In particular, the extensibility and elasticity of biological soft tissues such as ligaments and skins are affected by the quality and quantity of elastin fibers. However, the quantitative biomechanical contribution of elastin to the tissue properties remains unknown. The purpose of the present study was to investigate the biomechanical contribution of elastin fibers in biological soft tissues. Dorsal skins and yellow ligaments of rats were obtained and used for the experiments. Specimens of the skins and ligaments were immersed in an elastase solution for 3 hours at 37 degrees Celsius, and the mechanical loading tests were conducted for those specimens (elastase group) immediately after the enzymatic treatment. Normal skins and ligaments were used to obtain the data for the control group. The tensile strength of skins was approximately 9.0 and 10.3 MPa in the control and elastase groups, respectively. In contrast, the failure strain of skins was approximately 40.7% and 29.2% in the control and elastase groups, respectively. These results indicate the loss of elastin due to the elastase treatment is closely related to the skin extensibility rather than the strength. The failure load of ligaments was approximately 13.1 and 3.8 N in the control and elastase groups, respectively. Furthermore, the failure displacement of ligaments was approximately 2.1 and 1.3 mm in the control and elastase groups, respectively. These results show that the elastase treatment induces the reduction in the extensibility as well as the strength of the ligaments. It is known that the content ratio of elastin in the tissue dry weight is approximately 5% and 75% for the dorsal skins and the yellow ligaments, respectively. Such a difference in the elastin content between the skins and ligaments may be attributable to the change in their mechanical properties induced by...
the elastase treatment. In any case, it is concluded that elastin is an important component to maintain the mechanical integrity of the soft tissues.

**Key words:** Biomechanics, Biological soft tissues, Elastin, Skin, Ligament.

2. SESSION CIVIL ENGINEERING

A03. Study on Estimation of Optimum Mixing Conditions for Fiber-Cement-Stabilized Soil by Multilayer Neural Network

Moeka KUSE, Tomoaki SATOMI and Hiroshi TAKAHASHI  
*Graduate School of Environmental Studies, Tohoku University, Sendai, Japan*

Today, environmental issues have become a universal problem. Waste is also an inevitable environmental problem, and Japan has been promoting the effective use of many construction by-products. As high-water content mud like construction sludge is difficult to reuse directly on work site due to its physical properties and to prevent restoration works, rapid treatment of construction sludge is required. Fiber-cement-stabilized soil method that can make it possible to easily recycle high water content mud on work site has been developed, and besides, the method has been applied in actual construction. However, it has been taken a long work time and cost to determine the optimum mixing condition of the modified soil throughout laboratory tests.

Thus, this study focused on neural network which is part of artificial intelligence, and is effective for developing the non-linear relationship. Besides, this study developed a model for estimating failure strength and failure strain of Fiber-cement-stabilized soil from the mixing condition using neural network.

In order to develop a model for estimating the optimum mixing conditions of Fiber-cement-stabilized soil using neural networks, the hyperparameters of the neural networks were investigated using data from unconfined compression test of existing Fiber-cement-stabilized soil. As a result, a model was developed to estimate the fracture strength and fracture strain of the Fiber-cement-stabilized soil from the basic physical properties of the soil (soil particle density and particle size), water content ratio, amount of paper debris added, and amount of solidified cement added.

After that, unconfined compression tests were performed using specimens different from the mixing conditions of training data to accumulate test data for evaluating the usability of the developed model. As shown in Fig.1 and Fig.2, this study has revealed that the estimation errors of failure strength and failure strain are approximately plus or minus 50% of the measured values. Moreover, a flowchart to determine the optimum mixing condition of the modified soil was shown.

![Fig.1 Evaluation results of failure strength](image1.png)  
**Fig.1** Evaluation results of failure strength

![Fig.2 Evaluation results of failure strain](image2.png)  
**Fig.2** Evaluation results of failure strain

**Keywords:** Construction waste, Fiber-cement-stabilized soil, Recycling, Neural network, Unconfined compression
A04. Performance Evaluation of Soil Sampling Mechanism with Screw Auger

Masahide ISHIDA, Tomoaki SATOMI and Hiroshi TAKAHASHI
Graduate School of Environmental Studies, Tohoku University, Sendai, Japan

Every year, Japan is hit by many natural disasters such as volcanic eruption and landslide due to heavy rainfall. After these natural disasters occur, it is very important to recover the disaster sites as soon as possible. However, human cannot entry at disaster site because the ground is generally weak and possibility for secondary disaster is very high. If the volcanic ash and soil in the site can be sampled, the risk of secondary disaster will be estimated in more detail and reconstruction work plan will be proposed. In recent years, the use of unmanned aerial vehicle (UAV) is becoming common for disaster recovery work. UAV can access to the disaster site without being obstructed by terrain and be controlled remotely from safe place. Therefore, the development of a soil sampling system mounted on UAV is desirable. Although soil sampling systems has been developed in previous studies, it has not been possible to sample the soil at a sufficient depth to evaluate the ground strength.

The present study is focused on a screw auger. The screw auger is widely used for piling and can be sampled deeper with longer auger. Figure 1 shows the procedure of soil sampling with screw auger utilizing UAV developed the present study. First, the sampling system is carried by UAV at disaster site, Second, the rotating screw auger with fixed casing penetrate ground. After the maximum sampling depth is reached, the sampling system is pulled out from the ground by ascending UAV, and the UAV returns holding the soil in its system. However, the performance of soil sampling mechanism with screw auger, which is the basis of this system, is not clear. The purpose of the present study is to develop and evaluate the performance of soil sampling mechanism with screw auger. Specifically, various screw auger systems were manufactured, and laboratory experiments were conducted with different soil conditions to obtain the optimum penetrating condition of the auger. It was found that the screw auger system can penetrate up to 325 mm as shown in Figure 2. Moreover, the optimum screw pitch and thrust load for maximizing the performance of penetration under various soil conditions were obtained. Although mechanisms to take the counterforce of rotational penetration are needed, it indicates the soil sampling method using screw auger with casing has practical ability.

Fig.1 Procedure of soil sampling
Fig.2 Screw system after penetrating soil

Keywords: volcanic ash, unmanned aerial vehicle, soil sampling, screw auger

A05. Experimental Study on Effect of Bucket Angle on Excavating Resistive Forces for Crushed Rocks under Bucket Excavation

Kanna KAJI, Tomoaki SATOMI and Hiroshi TAKAHASHI
Graduate School of Environmental Studies, Tohoku University, Sendai, Japan
In crushed rock quarries, bedrock is generally crushed by explosives. The crushed rocks generated by blasting are scooped out by power shovels and they are transported by dump trucks to the crushing plant. There is a correlation between the work efficiency by these heavy machines and the grain size of the crushed rocks, besides, there is a correlation between the cost of resource development and the grain size. Therefore, it is important to generate the optimum grain size that satisfies both the work efficiency and the cost. Currently, a method of measuring the grain size of crushed rocks using image analysis has been proposed to check whether the crushed rocks have the optimum grain size for the evaluation of blasting performance. However, it takes a long time to conduct image analysis process, and the grain size of the inside of the deposited crushed rocks cannot be obtained. Therefore, the method to measure grain size using excavating resistive force has been proposed. However, in the previous studies, the excavation angle of the bucket was fixed for simplicity. The evaluation on the effect of the bucket angle on the excavation resistance is required, as the bucket angle is changed when the crushed rocks are scooped by the bucket.

The purpose of this study is to reveal the relationship between the grain size and the excavating resistive forces with different bucket angles. Specifically, crushed rock excavation experiments were conducted with different bucket angles and grain sizes. Figure 1 shows the schematic diagram of bucket arm movement of experiments and the definition of the bucket angle. In this study, the bucket angles of 0°, 30° and 60° were set. Figure 2 shows the relationship between the mean diameter and the average value of excavating resistive force in the case that the bucket angle is 0° and 30°. As shown in Figure 2, it was confirmed that the excavating resistive forces increase with increasing the mean diameter of crushed rocks when the bucket angle is 0°, and the same tendency was confirmed for a bucket angle of 30°, although, the increase of the excavating resistive forces were smaller than that for 0°.

Fig. 1 Schematic diagram of bucket arm movement and the definition of bucket angle

Fig. 2 relationship between mean diameter and average value of excavating resistive force

Keywords: crushed rocks; grain size; excavator bucket; resistive forces; bucket angle

A06. Study on Recycling of Reservoir Bottom Sludge as Banking Materials

Rina KASAI, Tomoaki SATOMI and Hiroshi TAKAHASHI
Graduate School of Environmental Studies, Tohoku University, Sendai, Japan

There are many reservoirs in Japan. This is because Japan has steep topography, river that has short flow channel and water runoff quickly. Reservoirs serve important roles as stable and valuable source of water for agriculture and also play a variety of roles in preventing floods and preserving ecosystems. On the other hand, most of them are more than 100 years old since construction and are deteriorating. Therefore, the possibility of breakdown of bank body around the reservoirs due to heavy rainfall has been increasing. In fact, Great East Japan Earthquake on
March 11, 2011, torrential rains in July 2018 and Typhoon No. 19 in 2019 caused the bank body of reservoir broken and serious damages to residential areas and farmland. In recent years, heavy rainfall that has never observed is not uncommon anymore. In addition, there is a possibility of a huge earthquake. That’s the reason why the reinforcement of bank body is required.

The reservoir also suffers from sludge accumulation on the bottom, which reduces the water storage capacity of the reservoir. The bottom sludge contains a large amount of water, which makes it difficult to transport and secure a disposal site. Therefore, it is desirable to make effective use of the bottom sludge locally. However, such bottom sludge doesn’t have the ability required for banking materials in its original condition. In addition, a large amount of banking material is necessary for the rehabilitation of the embankment. Previous studies have shown that tsunami sludge and river sludge modified by the fiber-cement-stabilized soil method have the ability as banking materials. In this method, paper debris and cement are mixed with high water content sludge to produce a good quality modified soil. The modified soil has high fracture strength, fracture strain, and high resistance to drying and wetting. In this study, we focus on bottom sludge in reservoirs containing organic matter. To propose a flowchart for modifying bottom sludge using fiber-cement-stabilized soil method, experimentally examine whether the modified sludge satisfies the ability for embankment material or not.

In this study, reservoir bottom sludge was sampled from water-drained reservoir in Tohoku region, Japan. The strength properties of the modified sludge were measured by unconfined compression test.

In consequence, the strength properties of modified bottom sludge depend on ignition loss and additive amount of cement. The larger the ignition loss, the more the hydration reaction is prevented, and the bonding of ettringite between soil particles is weakened. On the other hand, it was indicated that the modified sludge can satisfy the strength properties as banking material if the appropriate amount of paper debris and cement are added. The possibility of using bottom sludge of reservoirs as a banking material has been shown.

Keywords: Fiber-cement-stabilized soil method, Soil improvement, Application of bottom sludge of reservoir, Unconfined compression test, Organic matter

A07. Effect of the Additive Amount of Perlite By-products on the Strength Characteristic of Fiber-Cement-Stabilized Soil

Hina OMURO, Tomoaki SATOMI and Hiroshi TAKAHASHI
Graduate School of Environmental Studies, Tohoku University, Sendai, Japan

In Japan, a large amount of high-water content sludge is generated from construction sites and disaster sites of Tsunami and landslide. Since high-water content sludge is difficult to reuse as itself, it is disposed in the final disposal site. Recently, a new recycling method for high water content sludge was developed by using paper debris and cement. This is called “Fiber-cement-stabilized soil method”. As this method has several features such as high failure strength and strain and high durability, this method has already been used to recycle the construction sludge in many sites. In this method, paper debris is used for reducing superficial water content of sludge because of its high capacity of water absorption. However, recently, the cost of paper fragments is increasing. As a result, the recycling cost by this method is also increasing. Therefore, in order to reduce the construction cost, a new material with low cost to replace paper debris is strongly desired.

By the way, perlite by-products are industrial wastes discharged from production of perlite. Perlite is a forming material of volcanic rocks and perlite by-products are extremely fine powder of milled perlite. Since it is difficult to recycle by-products because of their small particle size,
they are currently being disposed in the final disposal site with high cost. On the other hand, as they have porous bodies, the ability of absorbing water is high. Moreover, since perlite is made from volcanic rocks, perlite by-products are environmentally friendly materials. As mentioned before, since the roll of paper debris in Fiber-cement-stabilized soil is to absorb the water, and absorbing water of perlite by-products is also high. Therefore, there is a possibility to use perlite by-products in this method. If they can be used to improve the high-water sludge, the reduction of additive amount of paper debris and recycling cost will be possible.

In this study, unconfined compression test is carried out to obtain the strength property of modified soil by Fiber-cement-stabilized soil with perlite by-products. The experimental result shows that the failure strength increases with increase of additive amount of both paper debris and perlite by-products (Fig. 1). It was indicated that perlite by-products work as a replacement of paper debris.

![Fig. 1 Relationship between additive amount of paper debris and failure strength](image)

**Keywords**: Fiber-Cement-Stabilized Soil, Perlite, Failure strength, Failure strain

A13. The Experimental Study on Influences in Load Carrying Capacity and Deformation Performance of RC Beam Due to Artificial Deterioration

Yilong CAO¹, Akihiko NISHIMURA², Xiu LUO³, Masao OKOSHI³, Wendong TANG², Hidekazu NISHIMURA¹

¹Graduate school of System Design and Management, Keio University, Japan
²Nishimura Seismic & Disaster Prevention Institute, Japan
³JR Soken Engineering Co.Ltd, Japan

Railway structures are important public infrastructures that support local economic activities, not only in terms of distribution, but also for tourism, etc. However, rising demand for maintenance management strategies for railway structures in Japan, is becoming a social problem owing to the simultaneous aging of these structures as the number of years that they have
been in service increases. In recent years, to improve the productivity in maintenance and renovation for railway infrastructure facilities, the research in implementation of robotics and artificial intelligence has been noticed. Whereas in 2020, the pandemic of the COVID-19 had a seriously influenced in daily-life and workstyle. Moreover, for avoiding the virus spreads caused by contact, lowering the density in working place, further, gradually utilizing the autonomous system will be the mega trend in maintenance of infrastructure facilities even railway systems in the future. When designing a maintenance and management system with a view of automation and labor saving, as a prerequisite, it requires to diagnose the condition of infrastructure facilities and components by using evaluation indexes accurately. Therefore, it is important to elucidate the mechanisms which relevant to deterioration of the entire infrastructure facility as well as its component parts, for assess their condition in quantitively. It has recognized that when the RC structure is severely damaged by an external force such as an earthquake, the capacity and deformation performance of the members are greatly reduced. However, there are few studies regarding quantitatively assess the impact of permanent material degradation on deformation performance. As preliminary research, this study takes the RC beam as the object, which is always constituted as a key member to various types of infrastructures. To grasp how the capacity and deformation performance of members change under the deterioration of concrete cover and/or rebars of RC beam due to salt-induced corrosion (Fig.1), firstly, the multiple model beams were created with different types of artificial deteriorations such as chipping of covers or/and cutting of hoop bars (Fig.2). Secondly, the static cyclic loading experiments were applied to the model beams, and the mechanical behavior were investigated. In addition, for the results of the static cyclic loading experiments, were verified through numerical analysis.

**Keywords:** RC beam; artificial deterioration; load-carrying capacity; deformation performance; static cyclic loading experiment.

### A26. Failure dynamics of a plate intruder in granular materials

Thanh-Trung Vo  
Bridge and Road Department, Danang Architecture University, Danang City, Vietnam  
E-mail: trungvt@dau.edu.vn

We numerically analyze the failure dynamics of a plate intruder embedded in cohesive and non-cohesive granular beds by using the extensive three-dimensional discrete-element method. The plate intruder with its rough surface is defined by gluing spherical particles, embedded at three
different depths, subjected to different pullout forces. The numerical method is employed with the inclusion of the capillary attraction forces and the lubrication forces between particles in the case of a cohesive granular bed. The pullout test is characterized by the responses of the intruder via its velocity and drag force and the mechanical properties of the granular bed during the rise of the plate intruder. We show that the intruder movement is proportional to the magnitude of the lifting force but inversely proportional to the level of the intruder embedment. Remarkably, the drag force exhibits different fluctuation sizes during the test, first represents the stable state, then shows a big noise due to the loading/unloading phenomena of the intruder. These observations are consistent with previous investigations as well as representing the good relationship between the pullout dynamics of an intruder and properties of a granular bed.

![Diagram](image)

**Fig. 1** Velocity profile and forces chain distribution during the pullout of an intruder.

A69. Failure Characteristics of the Granular Column Considering the Properties of the Material

Cuong T. NGUYEN$^1$ and Phuong T.T PHAN$^2$

$^1$Faculty of Vehicle and Energy Engineering, Phenikaa University, Vietnam

$^2$Institute of Mechanics, Vietnam Academy of Science and Technology, Hanoi, Vietnam

$^*$E-mail: cuong.nguyentien@phenikaa-uni.edu.vn

Granular flows occur in many aspects of our lives, from natural processes to pharmaceuticals, construction, agriculture, etc. Therefore, it is necessary to have a deep understanding of the granular flow characteristics. In this study, we study the failure characteristics of a two-dimensional (2D) granular column to determine the relationship between the initial size of the particle column (initial height $H_0$ and initial width $D_0$) to the shape (the height H and width D) of
the granular column after the failure. The dependent relationship of the post-failure size \((H, D)\) on the initial size \((H_0, D_0)\) of the granular column has been determined from the series of experiments as experimental functions. The failure characters of the granular column were recorded by high-speed cameras. This recorded data source was used to verify the numerical model developed using smoothed particle hydrodynamics (SPH) (Fig. 1a). The reliability of the experimental functions are once again confirmed from the calculation results of the numerical model for the cases which difficultly operated in the laboratory.

The above verified numerical model was used to implement series of numerical experiments on the failure of the granular column with the change of the material properties, namely the change in the internal friction angle \((\varphi)\) of the material. From these calculation results, new experimental functions are specified to illustrate the dependence of the post-failure parameters size \((H \text{ and } D)\) on the initial size \((H_0, D_0)\) and internal friction angle of material \(\varphi\) (Fig. 1b). The experimental functions then allow to quickly determine the shape of the granular column after the failure. These functions together with the images of the granular column's failure process recorded by high-speed cameras will be useful data, not only for the research and development of numerical models of granular flows but also for in-depth study of the granular flow’s characteristics.

![Fig. 1](image)

**Fig. 1** The failure process of the granular column (a) and the effect of the internal friction angle of the material on the relationship between \(H_0/H\) and \(H_0/D_0\) (b)

### A70. Effect of the Slope on the Failure Characteristics of Retaining Wall

Cuong T. NGUYEN\(^1\),*, Huyen T.T. TRAN\(^2\), Huong T.T. DUONG\(^2\), and Truong V. VU\(^1\)

\(^1\)Faculty of Vehicle and Energy Engineering, Phenikaa University, Vietnam

\(^2\)National University of Civil Engineering, Hanoi, Vietnam

*E-mail: cuong.nguyentien@phenikaa-uni.edu.vn

To limit landslides as well as keep slopes stable, retaining walls are one of the main regularly chosen solutions. Retaining wall with modular-block structure is quite popular due to its convenience such as easy in manufacturing, transporting, and constructing. One of the characteristics of this retaining wall type is the large density and high coefficient of sliding friction between blocks. In order to create the greatest possible resistance to the horizontal pressure of the soil (the landslide resistance of the retaining wall), the design of retaining walls plays an extremely important role. In this paper, we study the influence of the slope of rectangular-block retaining walls (RRW) on its stability, and also consider the failure characteristics of this type of
A series of experiments were performed with different slopes of RRW. In these material models, Aluminum rods of 1.6mm and 3mm in diameters, 50mm in length were mixed with the ratio of 3:2 in weights to make the model soil. Aluminum is also used to fabricate the wall block of 3.2cm in width, 2.5cm in height, and 5cm in length. The slope of the RRW is determined by the overlapping of the blocks ($\Delta x$). Experimental results have shown that it is not good when the slope of the RRW is too large or too small. In ordering for RRW to be as effective as possible, it is necessary to choose the right slope (Fig. 1 (a), (b) and (c)). Experiments also indicate that there are two different types of RRW failure: slip (Fig. 1b) and flip (Fig. 1c). The influence scope of these two types is also different. The failure process of these two types was recorded in detail by high-speed cameras. Our experimental results have shown the important role of slope in RRW efficiency, and also are a useful data source for researchers to verify numerical models. A numerical model using the smoothed particle hydrodynamics method (SPH) has also been developed that allows us to study the effect of slopes more deeply on the stability of RRW at a much lower cost than experimentally (Fig. 1 (d), (e) and (f)).

<table>
<thead>
<tr>
<th>$\Delta x$</th>
<th>(a)</th>
<th>22 mm</th>
<th>(b)</th>
<th>12 mm</th>
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<td></td>
<td>(d)</td>
<td>32 mm</td>
<td>(e)</td>
<td>12 mm</td>
<td>(f)</td>
<td>16 mm</td>
</tr>
</tbody>
</table>

Fig. 1 The effect of slope on the stability of retaining wall and the final state of the failure process obtained from experiments ((a), (b), (c)) and from the numerical results ((d), (e), (f)) where $\Delta x$ is the overlapping between the blocks.

3. SESSION FLUID DYNAMICS

A27. Visualization of Shear Stress Distribution Based on Flow Birefringence of Rheoscopic Fluid

Shuntaro Tanaka, Koichi Murase and Katsuaki Shirai
Department of Mechanical Engineering, Shibaura Institute of Technology, Japan
E-mail: md20055@shibaura-it.ac.jp

Shear stress is one of the fundamental parameters in viscous fluid flows. Shear stress on a solid surface is called wall shear stress, which is closely related to the wall friction and detection
of flow separation. In Newtonian fluid, shear stress is proportional to the velocity gradient related to the structural information of turbulent flow. Conventionally, shear stress is obtained as a velocity gradient measured with particle image velocimetry or hot-wire anemometry. While they provide velocities at multiple locations, the resulting velocity gradient suffers from large ambiguities at the calculation of the spatial derivative when the spatial distance becomes comparable to the spatial resolution. Therefore, it is desirable to measure the shear stress and velocity gradients not based on the spatial derivatives of the flow velocities. In recent years, measurement of flow birefringence has been conducted as a powerful diagnostic method for analyzing internal structure of complex fluids. It measures the molecular orientation and structural changes caused by polymer based on flow birefringence. Photoelastic measurement holds for birefringence and stress, although the conventional measurements remains pointwise. With the advent of polarization image sensors, we can obtain twodimensional flow birefringence at an instance without the need of calculating spatial derivative. We aim to realize quantitative visualization of shear stress in rheoscopic fluid flow containing flat particles exhibiting flow birefringence. If the method is established, it can contribute the analysis of velocity field and shear stress distribution at the same time. The ambiguity of calculating the spatial derivative will be reduced as well. We develop an experimental setup consisting of a stationary cylindrical container filled with rheoscopic fluid as shown in Fig. 1(a). The fluid driven by a transparent rotating disk parallel to the container bottom exhibits a rotating flow with a known shear stress distribution at a given angular speed. The polarization camera captures images of the circular polarized light passing through the test area. We analyzed the phase difference along the circumferential direction. The resulting phase difference exhibits periodic variations shown in Fig. 1(b). We found the phase difference variation is attributed to the manufacturing process of the transparent polymethyl methacrylate manufactured into the disk. After the measurement, we reduced the phase difference variation by replacing the disk made of glass. At the conference, we report on the measurement feasibility of the shear stress by comparing the results of the flow birefringence measurement with theoretical prediction and those in the previous research.

Fig.1 Experimental setup and initial result, (a) schematic of the experimental setup consists of rheoscopic fluid filled in a cylindrical container bound by a rotating disk on top, (b) average phase difference variation along the circumferential direction obtained with the setup.

**Keywords:** flow visualization, flow birefringence, polarization, rheoscopic fluid, shear stress
A28. Effect of Fine Content to Internal Erosion Susceptibility and Statistical Analysis for Gap-graded Soils

Dinh Minh TRAN\textsuperscript{1}, Thanh-Trung VO\textsuperscript{2}, Van Thao LE\textsuperscript{1}, Hoang Tri VU\textsuperscript{1}

\textsuperscript{1}Faculty of Road and Bridge engineering, The University of Danang - University of Science and Technology, VietNam
\textsuperscript{2}Danang Architecture University
E-mail: tdminh@dut.udn.vn

Suffusion is a selective erosion in which fine particles pass through voids of coarse particles due to a seepage flow. Thus, the content between fine and coarse grains has a great impact on erosion susceptibility. The main purpose of this paper performed suffusion tests for gap-graded soils with the fine content from 15\% to 45\% to study the role of fine particles on internal erosion susceptibility and using the multi-stage hydraulic gradient to investigate erosion classification based on the energy-based method. Results indicated that there were two trends related to fine content. Suffusion susceptibility increased with a fine particle content of 15\% to 35\% and the opposite trend when fine content is more than 35\%.

Besides, due to the great length of earth structures, and the heterogeneity of soils, it is important to optimize the experimental campaigns, thanks to statistical analysis. From the database of suffusion tests of our team and complementary tests performed on four gap-graded soils, an estimation of the erosion resistance index is proposed, which is based on physical parameters, which are quite easy to measure.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{pattern.png}
\caption{Patterns for gap-graded soils. (a) grain size distribution, (b) time evolution of hydraulic conductivity.}
\end{figure}

A30. Effect of submergence depth of water tank on the motion of a sphere launched vertically upward in water

Kotaro Takamure and Tomomi Uchiyama
Institute of Materials and Systems for Sustainability, Nagoya University, Japan
E-mail: kotaro.takamure@imass.nagoya-u.ac.jp

The water exit problem is a fundamental problem in fluid dynamics, and the behavior of the air–water interface and the energy transition of an object exiting water have not been thoroughly investigated. In this study, a solid sphere with a density of 2640 kg/m\textsuperscript{3} and diameter of $d = 25.4$ mm was launched vertically upward in water toward the air–water interface. The motion of the sphere and the behavior of the interface were investigated for varying submergence depths $H$ from...
the launch position of the sphere to the interface. The launch velocity was set so that the Reynolds number immediately after the sphere passed the air–water interface was about 3000 for all cases of H. Fig. 1 shows an example of the visualized images for \( H/d = 1, 3, \) and 6 to investigate the submergence depth dependence of the air–water interface behavior. Immediately after the sphere passes through the air–water interface (left figure in Fig. 1), it can be seen that the smaller the submergence depth, the smaller the amount of water entrained behind the sphere. When the sphere continues to rise in air (center figure in Fig. 1), a thin water column is observed behind the sphere for \( H/d = 1 \). Furthermore, the deeper the submergence depth, the thicker the water column, and the more water entrained around the sphere. When the sphere reaches approximately the maximum displacement position (right figure in Fig. 1), in the case of \( H/d = 1 \), a thin water column is still formed and no water mass is observed around the sphere. As seen in the right figure of Fig. 1(b), when \( H/d = 3 \), one narrow water column appears more clearly than when the sphere is rising (the center figure in Fig. 1(b)), and the water mass surrounding the sphere is scattered around the sphere as water droplets. In the right figure of Fig. 1(c), when \( H/d = 6 \), the water mass around the sphere forms a sheet, and the water column connecting the sphere and the free surface is thick and non-uniform. These results show that even when the sphere passes through the air–water interface at almost the same Reynolds number, the behaviors of the interface such as the water column and water mass behind the sphere are significantly different when the submergence depth \( H/d \) is different.

This work was supported by the TOYOAKI SCHOLARSHIP FOUNDATION, Japan.

Fig. 1 Sphere motion and air–water interface behavior for (a) \( H/d = 1 \), (b) \( H/d = 3 \), and (c) \( H/d = 6 \). Snapshot time progresses from left to right.

A31. Thermal Effect on Sound Emission Due to Water Entry of a Hydrophobic Sphere

Yoshiaki UEDA\(^1\), Hiroaki OHASHI\(^2\), Tomoya NAKAJIMA\(^3\) and Manabu IGUCHI\(^4\)

\(^1\)Faculty of Science and Engineering, Setsunan University, Japan
\(^2\)Graduate School of Science and Engineering, Setsunan University, Japan
\(^3\)Faculty of Mechanical Engineering, Osaka Prefecture University, Japan
\(^4\)Osaka City University, Japan

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This study aims to experimentally measure underwater sound emission generated from a sphere entering hot water. A transparent acrylic container (500 x 500 x 1000 [mm]) is partially filled with water. The container is also surrounded by a larger acrylic container filled with water. The outer bath is heated with the immersion heater so that the water in the inner container can be controlled at a predetermined temperature. A hydrophobic sphere having an equilibrium contact angle of 147 [deg] is set at h=60 [mm] and 200[mm] from the static freesurface level. At t=0 [s], the sphere is freely released and enters the water. Then, the hydrophobic sphere makes an axisymmetric cavity behind it. With the increase of time (but within a few tens of milliseconds), the cavity grows and collapses. At the collapse of the cavity, the instantaneous pressure fluctuation makes the huge sound. The behavior of the cavity growth and collapse is taken with the high-speed camera and the emitted sound is measured synchronously with the hydrophone. The sound signals are amplified and recorded with the PC via the data logger. Figure 1 shows the selected high-speed photographs and the output acoustic signal for a hydrophobic acrylic sphere with the diameter of d=17 [mm], released from h=200 [mm], entering water at the temperature of 26.5 [°C]. Also, the FFT result of the acoustic signal of Fig.1 are shown in Fig.2. It can be found that the sound with the predominant frequency of 400 [Hz] is monotonically emitted at the instance of the cavity pinching off. At the conference, we intend to present the thermal effect on the cavity behavior and the signals of the resultant emitted sound.

![Fig. 1 Acoustic signal and the cavity behaviors.](image1.png)

![Fig. 2 FFT result.](image2.png)

**A32. Wake of a sphere having a uniaxial through-hole in a uniform flow**

Hayato KATO\(^1\), Kotaro TAKAMURE\(^2\) and Tomomi UCHIYAMA\(^2\)

\(^1\)Graduate School of Informatics, Nagoya University, Nagoya, Japan
\(^2\)Institute of Materials and Systems for Sustainability, Nagoya University, Nagoya, Japan

E-mail: kato.hayato@a.mbox.nagoya-u.ac.jp

It is very useful to understand the characteristics of the flow past a bluff body, i.e., wake, under various conditions because wake is frequently observed in our life and has big effects on our environment. Many experiments about the wake of a sphere or a circular cylinder were carried out so far. Igarashi [1-2] placed a circular cylinder with a slit in a uniform flow to investigate the effect of the slit on the wake of the circular cylinder. When the slit was vertical to the streamwise direction, the boundary layer suction was observed periodically with the period of the vortex shedding. This suggests that the bluff body with slits enables the control of vortex shedding in the wake. In this study, a sphere with a uniaxial through-hole was placed in a uniform flow, and the
characteristics of the wake was investigated. The sphere diameter d was 25.4 mm, and the through-hole diameter was 6 mm. The sphere was fixed by a rod, whose diameter was 2 mm. The coordinate origin was the center of the sphere, and x, y, and z represent the streamwise, spanwise, and vertical directions, respectively. The sphere was installed so that the uniaxial through-hole was parallel to the y-axis. The flow velocity was measured by a hot-wire anemometer (KANOMAX 7000ser.). The uniform flow velocity U₀ was 7 m/s and the Reynolds number based on d and U₀ was almost 12,000. Fig.1 shows the spanwise distribution of the streamwise mean velocity, and the error bar indicates the rootmean-squared velocity fluctuations. Fig.1 (a) and (b) indicate the distributions in the cases of without and with the through-hole, respectively. At x/d = 1, the velocity defect of the sphere with the through-hole was smaller. At 2 ≤ x/d ≤ 13, the significant differences weren’t observed with or without a through-hole. The error bar was bigger in the region rear the sphere. This is caused by the large-scale vortex shedding due to the separation of the flow from the sphere surface.

This work was supported by the TOYOAKI SCHOLARSHIP FOUNDATION, Japan.

![Fig.1](image1.png)

**Fig.1** Spanwise distribution of the streamwise mean velocity. (a) Without a through-hole, (b) with a through-hole.


A33. The Mechanism of the Separation Control by a Wing with Leading Edge Protuberance and Tandemly Arranged Wings with Linear Leading Edge

Ayami UEKI¹, Takahiro YASUDA², Hisato MINAGAWA²

¹Graduate School of Engineering, The University of Shiga Prefecture, Japan
²School of Engineering, Japan

A study on the wing performance and the passive separation control of two tandem arranged NACA0012 wing using leading edge protuberance in low Reynolds number was conducted. In this study, we performed a wind tunnel experiment to investigate the mechanism of the separation control of a wing with leading edge protuberance (LEP) and compared with that of a wing with liner leading edge. The experiments were performed by using open-circuit wind tunnel at The
University of Shiga Prefecture. We measured the lift forces acting on a backward wing with wing with liner leading edge and one with LEP which located at the unit cord length downstream from the trailing edge of the forward wing. Then we measured velocity and turbulence distributions above the upper surface of the backward wing. As shown in Fig. 1, in the case of tandem arranged wing with linear leading edge, the stall angle was delayed by 4 degrees and the lift force coefficient was improved compared with the single wing. On the other hand, in the case of wing with LEP, the lift force was not changed regardless of the number of wings. Then, to clarify the mechanism of the separation control, we investigated the mean velocity of the X (streamwise) - direction \( u/U \) and velocity fluctuation of the Z (span)- direction \( u'/U \) as shown in Table 1. The velocities in the case of tandem arranged wings were larger than those of single independent of leading-edge shape. Therefore, it is found that in the case of tandem arranged wing, the turbulent flow formed by the forward wing suppresses the flow separation of backward wing. Whereas, in the case of the single wing, the mean velocity becomes small due to the flow separation. It is noted that the single wing with LEP maintains the high lift force in spite of such small mean velocity. It is guessed from the larger spanwise velocity fluctuation in the case of LEP that the single wing with LEP enhances the reattachment of the flow by the spanwise secondary flow (longitudinal vortices) induced by LEP.

![Fig. 1 Lift force coefficient.](image)

(a) Wing with liner leading edge  
(b) Wing with LEP

<table>
<thead>
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<th>Arrange</th>
<th>( u/U )</th>
<th>( u'/U )</th>
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</thead>
<tbody>
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<td>Wing with liner leading edge</td>
<td>Single</td>
<td>0.133</td>
<td>0.0467</td>
</tr>
<tr>
<td>Wing with LEP</td>
<td>Single</td>
<td>0.215</td>
<td>0.0733</td>
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<td>Wing with liner leading edge</td>
<td>Tandem</td>
<td>1.140</td>
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<td>Wing with LEP</td>
<td>Tandem</td>
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<td>0.1267</td>
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</table>

A34. Study of Fluid Drag Acting on Tandem Car Models

Syouta SONOKI\(^1\), Hideaki MONJI\(^1\), Sungchan HONG\(^2\) and Takeshi ASAI\(^2\)

\(^1\) Department of Engineering Mechanics and Energy, University of Tsukuba, Japan

\(^2\) Institute of Health and Sports Science, University of Tsukuba, Japan

E-mail: monji@kz.tsukuba.ac.jp

The drag force acting on cars in tandem arrangement has been studied by using a wind tunnel or a passing water tank in the range of Reynolds number of 8.0×10^3 to 10^6. Generally, it is supposed that the drag force on the following car is reduced by the presence of the leading car, which is called as the slip stream effect. However, in the previous study, it was found that the drag force on the following car increased comparing with that of the single car in the specific conditions.
both of the distance from the leading car and the Reynolds number. To investigate the phenomena, we visualized the velocity field around car models by CFD and PIV. Figure 1 shows the drag force ratio, $F/F_0$, on the following car with the normalized intervehicle distance, $e/L$, in the experiment using reduced car models in a wind tunnel under several conditions of Reynolds number. Here, $F$ is the drag force acting on the following car model and $F_0$, it on a single car model in the same flow velocity. Therefore, the drag force acting of the following car is smaller than that on a single car mole for $F/F_0 < 1$, and vice versa. In case of $Re=8000$, the drag force ratio is smaller than 1 for all $e/L$. The $e$ is the distance between the leading and following cars, and the $L$ is the length of the reduced car model. It is interesting that the drag force ratio at $e/L =0.8$ increases with the Reynolds number. The drag force ratio exceeds 1 for $Re=106$ and the distribution of the drag force ratio along the inter-vehicle distance has the maximum at $e/L =0.8$. The drag force ratio larger than 1 means that the following car receives a larger drag force than that acting on a single car, or the slip stream effect cannot be found. Figure 2 show the velocity filed around a car obtained by PIV for $Re=2\times10^5$. Figure 2 (a) shows the velocity filed around the front of a single car and (b) shows it of the leading car for $e/L=0.4$. The flow velocity if Fig. 2 (b) decreases because of the presence of the leading car. As the result, the drag force on the following car also decreases. As the same time, the flow reduces at a corner of the front of the leading car, which induces increase of the drag force based on the streamline curvature theorem. The reduced flow in front of the leading car has both effects of increase and decrease of pressure on the leading car.

![Fig. 1 Drag force ratio of the following car along the inter-vehicle-distance for several conditions of Reynolds number.](image1)

![Fig. 2 Velocity field around the front of a car (Re=2\times10^5).](image2)

**A43. Experimental investigation of laminar separation bubbles on a series of teardrop cylinders with increasing thickness**

Diane Scoboria\(^1\)*, Louis Wu\(^2\), Sam Li\(^2\) and Jiun-Jih Miau\(^3\)
\(^1\)Full-time research assistant, Department of Aeronautics and Astronautics
\(^2\)Master graduate student, Department of Aeronautics and Astronautics
\(^3\)Professor, Department of Aeronautics and Astronautics
National Cheng Kung University, Tainan, Taiwan 70101
*Corresponding Author: Diane Scoboria; email: diane.scoboria@gmail.com

The phenomena of laminar separation bubble (LSB) and drag crisis are investigated on a series of teardrop cylinders with increasing thickness (width/chord ratio = 0.2, 0.3, 0.4, named T20, T30, and T40, respectively). Oil film visualization and surface pressure measurements were conducted to examine the flow characteristics near the surface. Subsequently, the drag and lift
coefficients named $C_d$ and $C_l$, respectively, were derived from surface pressure data. Wind tunnel experiments were performed over a range of Reynolds numbers ($Re = 2.8 \times 10^4$ to $1.5 \times 10^5$) and angles of attack ($AOA = 0^\circ$, $0.5^\circ$, $1^\circ$, $2.5^\circ$, $5^\circ$, $10^\circ$).

Low Reynolds number aerodynamics ($Re \sim 10^4$) is a regime where the viscous boundary layer phenomenon plays a prominent role, which has not been fully explored due to the complexity of the laminar-to-turbulent transition process involved. It can be characterized by unpredicted aerodynamic performance due to the emergence of the drag crisis, brought on by the formation of LSB.

In this study, critical findings show that increasing model thickness results in LSB formation at higher $Re$ and with an increase in $Cp_{rms}$, denoting the root-mean-square value of instantaneous pressure coefficients reduced from the pressure measurements on the model surface. In addition, the $C_d$ results obtained for the T30 and T40 models shows that the former had lower $C_d$ at all $Re$ and $AOA$ examined.

Additional findings indicate that a strong negative $C_l$ on the T40 at moderate $AOA$ is due to the formation of a windward side LSB. The windward side LSB formed at a lower $Re$ compared to the leeward LSB and remained the presence at higher $AOA$.

Ongoing investigation is being made to examine the intermittent formation of the short time scale LSB and bursting in the critical regime. The results obtained would provide new insights into blunt body aerodynamics. A better understanding of LSB characteristics can potentially have impact on optimizing UAV flight at low Reynolds numbers.

Keywords: Laminar separation bubble, transition regime, drag crisis, teardrop cylinder, boundary layer.

A44. Visualization of Flow around Turrets of Cup Labeling Machine

Naoki Matsumoto¹, Takahiro Yasuda¹, Hisato Minagawa¹, Ogawa Takashi², Yoshinobu Takayama², Takanori Miura²
¹Graduate school of Engineering, The University of Shiga Prefecture, Japan
²Kohoku Seiko Co., Ltd, Japan.
E-mail: os22nmatsumoto@ec.usp.ac.jp

Cup printing machine is a machine that printed labels on plastic cups. The machine consists of a turret part rotating intermittently and a mandrel part rotating continuously. It can produce 200 pieces of cup per minute. Corona discharge treatment is performed as a pre-processing of printing in order to improve adhesion of ink to label. However, corona discharge treatment generates ozone and the ozone is scattered over a wide area due to the flow caused by the cup printing machine. As a result, ozone reacts with the body surface of the machine and causes oxidative degradation. Therefore, it is important to predict the ozone scattering range to the absorb ozone. However, since ozone is invisible, it is difficult to know the scattering range. Our final goal is predicting the ozone scattering range by computational fluid dynamics (CFD). In order to evaluate the validity of the CFD result, the comparison with visualization experiment is necessary. Therefore, in this study, flow visualization around cup printing machine was carried out using a full scale model of cup printing machine and the results were compared with those obtained by the calculation results. The experimental equipment for visualization was consist from turret part with cup, laser irradiate device, smoke generator and high speed camera. The smoke was generated at the same position as the corona discharge equipment. The smoke flow was lighted by laser sheet and recorded by a high speed camera. From the recorded images, velocity vector was analyzed by particle image velocimetry (PIV). Fig. 1 shows the front view of flow around a cup obtained by the visualization experiment and the numerical simulation using STAR-CCM+ (Siemens Co. Ltd). It was found from
the front view that the smoke flow drawn to the cup in front and the flow pushed out by the cup were confirmed. These flow patterns were agreed with those obtained by the numerical results. Therefore, the numerical result is thought to be reliable for predicting the flow around the cup printing machine.

**Fig.1 Flow visualization around cup.**

**Keywords:** PIV, flow visualization, Corona discharge treatment, ozone, cup printing machine

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A46. Periodic droplets splashing from water jet accompanied with air suction

Tsutomu ISHIDO, Yuta ISHII and Hiroaki HASEGAWA
Graduate School of Engineering, Utsunomiya University, Tochigi, Japan

It is found that when water with free surface in a reservoir is pressurized using air and spouted as a jet from nozzle attached to the bottom of the reservoir, aligned droplets occurs from the jet. The aligned droplets from the jet are splashing explosively and periodically to radial outside of the jet. Conceptual sketch of this phenomenon was shown as Figure 1. This periodic droplets splashing phenomenon has characteristic frequency by changing nozzle shape. In this study, water jetting tests were conducted using nozzles of several shapes and changing added air pressure. Periodic droplets splashing phenomenon was analyzed by using high speed photography and pressure measurement. The purpose of this study is to clarify the effect of the air suction condition at inlet part of nozzle on the jet in the periodic droplets splashing phenomenon. From those photographs, it was found that periodic droplets frequency of axial direction of jet depends on the nozzle shape especially nozzle length.

Figure 2 shows the schematic diagram of flow visualization system performed image analysis. Cylindrical acrylic resin reservoir with an inner diameter of 130 mm is filled with water, and air pressure is applied to the water to generate a vertical jet of water by removing the plug from the nozzle attached to the bottom of the reservoir. This water jet is photographed by a highspeed camera.

Most typical result of this study are shown in Figure 3. The length of the two red lines represents the nozzle length h, and the distance between them represents the nozzle inner diameter d. The nozzle length of Figure 3(a) is h=5mm, and that of Figure 3(b) is h=2.5mm. The inner diameter of both nozzles is the same of d=2mm. The distance between droplets scattered in the radial direction of the jet axis (the length of the blue line in Figure 3) is longer in Figure 3(a) than in Figure 3(b). In other words, Figure 3(a) shows low frequency droplets splashing and Figure 3(b) shows high frequency droplets splashing. Therefore, it was found that the shorter the nozzle length, the higher the frequency.
A48. Comparison of Flows Around UCAV Models of Blunt Apex

Y. H. Chen¹, L. Y. Chen¹, I. Madan¹, J. J. Miau¹ and S. Mat²
¹Dept. of Aeronautics and Astronautics, National Cheng Kung University, Tainan, Taiwan 70101
²Faculty of Engineering, Universiti Technologi Malaysia 81310, Skudai, Johor, Malaysia

The aerodynamic configurations of Unmanned Combat Aerial Vehicles (UCAV) are notably featured with round leading edges and variable thickness of wing cross-sectional profiles. The SACCON model is the one in this category, which was studied by NATO Science and Technology Organization (STO), the task groups of AVT-161 and AVT-183 [1]. In viewing that the complexity of the form factor of the SACCON model makes the aerodynamic flow difficult to comprehend, researchers [1] alternately proposed to a diamond wing as a base mode enabling to look into the flow phenomena of concern in detail.

SACCON is known for the characteristic of sharp-blunt-sharp leading-edge transforming from the wing apex to tip, shown in Figures 1 and 2. Moreover, the diamond wing is designed based on NACA64A006, shown in Figure 3. The leading edge of the diamond wing is characterized by a radius of curvature comparable to that of SACCON at the blunt leading-edge portion. In terms of $\frac{r_{le}}{C_{ref}}$, where $r_{le}$ is the radius of the leading edge and $C_{ref}$ is the chord length, it is 0.246 % for the diamond wing and 0.23 % for the SACCON model. At low angle of attack, flow over the blunt apex of either model would attach on the wing surface. At higher angles of attack, flow could separate from the wing surface, but not at the apex due to the roundness of the leading edge that delay flow separation to a chordwise location downstream. For instance, according to Luckring, J. M.[1] on a diamond wing, at 12 degrees of angle of attack, the separation vortex rolled up at the mid leading-edge location but the incipient flow separation took place upstream of this location. On the other hand, for the SACCON model, flow development at low angle of attack was predominant by the geometrical effect of the blunt-leading edge, thus flow remained attached on the model surface. The separation vortex was seen at higher angle of attack.

In this study, experimental efforts were made to compare the aerodynamic flow characteristics of a SACCON and a diamond wing models, particularly the flow structures near the
apex of the two models. The independent parameters considered in experiment include the angle of attack and the Reynolds number. Experiments were carried out in a low-speed wind tunnel using the oil-film and tuft methods. The main objective is to gain better understandings about flow behaviors near the model surfaces subjected to different angles of attack and Reynolds numbers. The results obtained will be presented and discussed in this paper.

Figure 1. The SACCON model employed in this study, (a) top view (b) side view (c) front view.

Figure 2. Illustrations of the wing cross-section profiles of the SACCON model for the cross sections, and indicated in Fig. 1.

Figure 3 The diamond wing model.

Keywords: flow visualization, oil film, UCAV, blunt apex, SACCON, diamond wing
The highly radioactive components in spallation neutron source in MLF/J-PARC should be classified and cut partly for the backend treatment taking radioactive levels into account. Although laser-cutting technique is prospective for cutting them remotely, it is difficult to mitigate the secondary contamination due to the spattering phenomena, etc. caused by the rapid high intense thermal loading. Scattering of radioactive dust such as fume and sputtering, which is generated throughout laser cutting process, gets to be a major issue for practical usage in cutting highly radioactive substances. However, the physical behaviors in molten pool accompanied by spatter and fume generation have not been elucidated in detail because of the complicated phenomena, including the multi-phases dynamics of solid, liquid, and gas in localized area. Therefore, we focused on the phenomenon that cavitation collapses near the surface and droplets scatter as one of the factors related to the elucidation of spatter scattering. In this study, in order to elucidate the mechanism of spatter scattering, The technique of spark discharge underwater was availed to precisely generate a cavitation bubble. The growth and collapse behaviors influenced by the interaction between free surface and bubbles resulting the spattering phenomena are directly observed by using ultra-high-speed photography. Additionally, the numerical simulation was carried out using CRIMSON (CIVA Refined Multiphase flow simulation code) originally developed by one of authors. As a result, it was found that the smaller the distance between the bubble and the water surface, the higher the scattering height and velocity, and the shorter the time to collapse, and that the trend was describable numerically as shown in Fig. 1. The detailed comparison will be presented in the conference.

Fig. 1 Experimental and numerical observation of bubble collapsing and spattering behavior for different time after spark discharge; upper pictures were taken by a ultra-high-speed camera, lower ones numerically simulated results.
A51. Using the Diagonal-swap Technique to P2P1 Grid for Simulating of FSI Problem with Large Deformation of Solid

Sang Truong Ha*, Nguyen Van Que, Vu Van Chien, Vu Manh Hieu, Ta Xuan Tung
Faculty of Mechanical Engineering, Le Quy Don Technical University, Viet Nam
*E-mail: sanght.st@lqdtu.edu.vn

Fluid-Structure Interaction (FSI) has received much attention in recent decades due to its critical applications, which can be found in many fields of science and engineering. When the solid deformation is large, the FSI simulation has become challenging because the fluid grid has a large disproportion. A re-meshing procedure is commonly adopted to generate a new grid in the fluid sub-domain after a certain amount of computational time to overcome this difficulty. In addition, a smoothing approach or changing the connectivity of elements is also can be used for this issue.

In this paper, the diagonal-swap technique is employed to improve the P2P1 grid for simulating an FSI problem with the large deformation of a solid. After the swapping process, an interpolation is also used to update the values of velocity on the middle nodes of the triangle element. The technique can be combined with a smoothing approach such as Laplace smoothing to enhance the mesh quality in a small time. The finite element method (FEM) is used to solve both the fluid and the structure regions. The interaction of the flow and structure at the interface is solved by using a strong coupling algorithm. Several FSI benchmark problems on 2D are examined, and it is shown that the proposed method has a good performance in terms of efficiency and straightforward implementation.

![Fig.1 Pressure field with large deformation of solid](image)

![Fig. 2 Unstructured grid. (a) without diagonal-swap, (b) with diagonal-swap](image)
Investigation of Pressure Wave Propagation Behavior in Magnetorheological Fluids Using an Experimental Equipment that Incidents Plane Waves

Daiki TANAKA¹, Yuma MATSUOKA¹, Kohei TATEYAMA², and Keiko WATANABE²
¹ Major in Advanced Mechanical Engineering and Robotics, Ritsumeikan University, Japan
² Department of Mechanical Engineering, Ritsumeikan University, Japan
E-mail: keikow@fc.ritsumei.ac.jp

Magnetorheological (MR) fluids are categorized as smart fluids, which are made of ferromagnetic particles suspended in carrier fluids such as silicone oil. On application of an external magnetic field, the ferromagnetic particles are arranged along the magnetic flux line. It is called a cluster. The flow characteristic changes according to the cluster and it has anisotropy. In the previous study, the authors have conducted high-speed impact experiment on MR fluids and examined the propagation behavior of pressure waves induced by impacts. The results suggest that clusters affect pressure waves propagation behavior. However, while clusters in MR fluids have an anisotropy, pressure waves induced by impacts are spherical waves, and it is difficult to elucidate in detail the effect of clusters on pressure wave propagation behavior. Therefore, in this study, we conducted an experiment to incident a plane wave, and investigated the pressure wave propagation behavior. The equipment consists of a striker, an incident bar, and a specimen. The specimen was filled with MR fluids in a circular tube. The one side of it was closed by the incident bar with O-ring. The other side was sealed with a rubber stopper. The stress wave generated when the launched striker had collided with the incident bar became a planar wave by passed through the incident bar and propagated to the specimen. A strain gauge was installed axially on the incident bar to measure the stress propagating from the obtained strain. Four pressure sensors installed in the specimen measure the pressure at different propagation distances and investigated the pressure wave propagation rate in the liquids and the attenuation of the pressure wave. Three types of MR fluids were prepared with the ferromagnetic particle concentration of 6 vol%, 15 vol% and 30 vol%. As a result of the experiments, the increase of ferromagnetic particle concentration enhanced the wave propagation rate. In addition, the experiment was conducted with different magnetic field strengths and directions. Consequently, it was elucidated that the effect of magnetic field strength on pressure wave propagation behavior. It was also confirmed that the anisotropy of MR fluids.

Keywords: Magnetorheological Fluids, Plane Wave, Particle Concentration, Anisotropy, Attenuation

Boundary Layer Control Using Synthetic Jets in a Two-dimensional Diffuser

Naoto KATO, Takuma NAGASAKI and Hiroaki HASEGAWA
Graduate School of Engineering, Utsunomiya University, Tochigi, Japan

Synthetic jets are expected as a new method of active boundary layer control because its actuator is advantageous than steady jet system in terms of less operating power, zero-netmass-flux and smaller in size.

From the viewpoint of boundary layer control, the structure of the trailing legs extending from the wall surface is important, which is generated by the interference between the vortex ring blown by the synthetic jets and the crossflow. In addition, fluid near the wall with small momentum is transported outside the boundary layer by the induced velocity by the trailing legs. Therefore, it is necessary to keep the trailing legs near the wall in order to promote mixing the crossflow and the boundary layer. However, the structure of trailing legs on the boundary layer control has not been
clarified yet. In this study, the ratio of the jet velocity to the crossflow velocity are focused on and visualization experiment is conducted to clarify the structure of trailing legs in the vortex ring blown out by the synthetic jets and its effect on the boundary layer control.

Figure 1 shows the schematic diagram of experimental setup. The wind tunnel is an open type and its cross section of the measurement section is 250 mm × 120 mm. The orifice of the synthetic jet was installed at the bottom of the wind tunnel. The coordinate system was set to the center of the orifice. X, Y, and Z are defined as downstream distance from the orifice, height from the bottom, and span direction respectively. One orifice of the synthetic jet was installed at the center of the measurement section, and its diameter was 7 mm. The frequency of the synthetic jet was set to 100 Hz. The velocity ratio VR is defined as VR=Vj/U0 where Vj is the jet velocity and U0 is the crossflow velocity, respectively. In the visualization experiment, we used a continuous light laser and a high-speed camera. The tracer smoke used for visualization filled the cavity part of the synthetic jet and was blown out through an orifice.

The experiment was conducted with three patterns of VR = 0.7, 1.0, and 1.5. The smaller value of VR was more effective than the higher on the boundary layer control. It is observed that there is a difference in the location of the vortex ring from the wall due to VR (Fig. 2). When VR is 0.7, the vortex ring can be confirmed to exist near the wall and the smoke extending from the vortex ring to the wall can be clearly seen. It is certain that the smoke is the trailing leg as reported by previous researches. This smoke flow has vorticity and promotes the mixing of the boundary layer and the crossflow. It is suggested that the trailing legs promotes the control effect when the VR is small.

![Fig.1 Schematic diagram of experimental setup.](image1)

![Fig.2 Smoke Flow visualization of synthetic jet in crossflow](image2)

**A68. Vortex Structure in the Wake of a Three-Dimensional Airfoil during Impulsive Incidence Variation**

Naoto KATO, Kazuki UEDA and Hiroaki HASEGAWA  
Graduate School of Regional Development and Creativity, Utsunomiya University, Japan

Recent researches showed the behavior of tip vortices took an important role in unsteady fluid forces. In this study, investigation of three-dimensional structure of tip vortices is carried out to research the role of tip vortices in the unsteady lift. Three types of airfoils, discoid, rectangular, and triangular shapes are tested. The relationship between tip vortices and characteristics of unsteady lift was investigated by wind tunnel experiment when the angle of attack of an airfoil was impulsively varied.
Figure 1 shows the schematic diagram of experimental setup. The cross-section of the test section is 300 mm square. The origin of the coordinate system is defined at the center of the discoid airfoil and rectangular airfoil and 2/3 chord lengths of delta airfoil. The dimensionless measurement time $tU_0/c$ is derived from the measurement time $t$, freestream velocity $U_0$, and chord length $c$. In the present study, the angle of attack was varied from zero to those angles which was larger than the static stall angle, and maintained till the end of the experimental runs. Figure 2 shows the lift coefficients under dynamic and static conditions for the discoid airfoil and the triangular airfoil, respectively. Unsteady lift attained impulsively larger value than that under the static condition after the impulsive incidence variation, and asymptotically decreased to the static one. The rate of increase in CL at the change in angle of attack relative to maximum of CL at the static condition was larger for triangular airfoil than for the discoid airfoil. Figure 3 shows the flow visualization of triangular airfoil viewed from the downstream. The red dashed line in the figure shows the outline of the triangular airfoil. Vortices with different directions of rotation can be seen at the trailing edge. This tip vortex was larger than the static counterpart. The strong entrainment of the flow at the change of the angle of attack was more remarkable for the triangular airfoil than for the discoid airfoil. This behavior of the tip vortex seems to affect the lift characteristics.

4. SESSION HEAT AND MASS TRANSFER

A74. Study on the selection of operating parameters of Yanmar diesel engines on cruise ships for remote monitoring to ensure safety in operation at Khanh Hoa sea

HO Duc Tuan
Faculty of transportation Engineering, Nha Trang University, Viet Nam
Email: tuanhd@ntu.edu.vn

Diesel engines have advantages over gasoline engines, such as higher engine efficiency or diesel fuel is cheaper than gasoline, so Diesel engines are widely used in industries, mainly occupying unique in the shipping industry. Monitoring of the main diesel engine is mandatory for the traffic vessels. For the convenience of the diesel engine operator, who is also the operator on
a cruise ship, selecting parameters for remote monitoring from the ship's control position is essential to ensure the ship's main engine during operation safely. This paper presents the theoretical basis of selecting operating parameters to monitor the main engine of a cruise ship to increase the life and reliability of the main diesel engine and protect the safety of the traveling vessels.

**Keywords:** Operating parameters, Yanmar engines, remote monitoring, cruise ships, engine reliability.

### A75. Study on establishing a technical state’s diagnostic model of the main diesel engine for the small fishing vessels

Ho Duc Tuan¹, Mai Duc Nghia²

¹Faculty of transportation Engineering, Nha Trang University, Viet Nam  
²2nd Faculty of Mechanical Engineering, Air Force Officer’s college, Nha Trang City, VietNam

Email: tuanhd@ntu.edu.vn  
Email: nghiamaiduc@gmail.com

When using a diesel engine as the main engine on a fishing boat, the absence of the measuring and testing equipment can lead to a decrease in safety, reliability, and danger to people and ships. Therefore, establishing a diagnostic model of the engine's technical state through the high-pressure pipelines pressure and the end-of-stroke compression pressure will help improve working efficiency and prevent problems. In this study, we experimentally verified the diagnostic model on the 4-CHE Yanmar engine. The results show that when the high-pressure pipeline's pressure is declined to 16% and the end-of-stroke compression pressure is reduced to 12%, the engine's power is reduced by 19.85%, and the soot emission of the engine increases to 32.60%.

**Keywords:** high-pressure pipeline's Pressure, end-of-stroke compression pressure, fuel injection pressure, power, soot emission, fuel injection system, main diesel engine, fishing boat.

### 5. SESSION INSTRUMENTATION AND TESTING

### A23. Impact Indentation Test of Pure Ice by Direct Impact Hopkinson Bar Method Using Conical Indenters

Yuki NAKAO¹, Hiroyuki YAMADA² and Nagahisa OGASAWARA²

¹Graduate School of Science and Engineering, National Defense Academy, Japan  
²Department of Mechanical Engineering, National Defense Academy

E-mail: em57009@nda.ac.jp

The deformation and fracture properties of ice have attracted considerable research interest. The strength of ice has been reported to depend on the temperature, strain rate, and other factors, and several studies have addressed that ice exhibits ductile or brittle behavior depending on the strain rate. Notable ice fracture phenomena include the fracturing of ice with an ice pick or the fracturing of ice when struck with the back of a metallic spoon. However, the fracture mechanisms which can explain these phenomena have not been clarified. In the previous study, we conducted quasi-static indentation test using conical and spherical indenters, and experimentally showed that the shape of the indenter has a significant effect on the deformation and fracture behavior of pure ice. In this study, we focus on the impact fracture of pure ice to clarify the effect of strain rate on deformation and fracture phenomena.
Commerciarily available pure ice processed into 20 mm cubic was used as the test material. The impact indentation test was conducted by applying direct impact Hopkinson bar method. The test apparatus consists of a striking bar, a supporting bar, a launching device that launches the striking bar by a spring mechanism, and a chamber connected to a cooling system using liquid nitrogen. The specimen was set on a mount made by combining aluminum alloy and polycarbonate, then attached to the supporting bar, and fractured by the impact of the striking bar. The striking bar was a circular tube with a length of 2000 mm, and conical indenters with indenter angles (apex angles) of 90, 120, and 140° were attached to the tip. The load was obtained by measuring the elastic stress wave generated during indentation using strain gauges mounted on the striking bar. Neodymium magnet and coils were mounted on the striking bar, and the velocity of the striking bar was measured using the induced electromotive force generated by the magnet passing through the coils. The average velocity of the striking bar was approximately 2.3 m/s. The tests were performed at an ice temperature of -10.1 ± 0.3℃. The states of deformation and fracture of the ice specimen were recorded using a high-speed camera (MEMRECAM ACS-1; nac Image Technology Inc.) with frame rates of 200000 fps installed in front of the observation window of the chamber and an LED light illuminated from the opposite side of the high-speed camera.

The test results showed that the load when the ice fractured (fracture load) decreased with decreasing indenter angle. In addition, the amount of displacement at the instant of fracture decreased as the indenter angle increased. These tendencies were similar to the quasi-static indentation test. Furthermore, the fracture load was larger than that of the quasi-static indentation test, and this tendency was consistent with the uniaxial compression test. Therefore, it was suggested that this method is capable for evaluating the strength of ice at impact strain rate.


Wei JIANG, Takuya HARA, and Motoharu FUJIGAKI
Graduate School of Engineering, University of Fukui, JAPAN
E-mail: jiang@g.u-fukui.ac.jp

Displacement measurement of large infrastructure structures such as bridges, towers and skyscrapers are important for preventing accidents. In this study, we proposed a method that can generated multiple parallel laser lines without using complexity optical system. Our method is put a diffraction grating in front of the camera or the laser, as shown as Fig. 1. Since laser line pass through the grating before imaging, parallel laser lines of the same interval, which can also be called laser parallel fringes, will generated in a camera.

Figure 2 shows the experiments device. A plastic cantilever was used as a measuring object. A vibration damping experiment was carried out by touching the cantilever with a finger. An industrial camera, a green laser with line projection function and a diffraction grating were used as experimental devices. Object images with laser parallel fringes projection during vibration were taken by the camera. The frame rate was 100 fps. The captured images were calculated by a weighting phase analysis method.

Figure 3(a) shows the result of out-plane-displacement of a cantilever measured by the phase analysis method. A damping curve was measured, which means that the proposed method measured the vibration successfully. Figure 3(b) shows an enlarged view of the damping curve. This result indicates that a minute vibration with an amplitude of 10 µm can also be measured.
A41. Prototype of a Reflective Photoelastic Experimental Apparatus for Evaluating Residual Stress in DLC Films

Keita TANUMA and Kenji GOMI
Department of Mechanical Engineering, Tokyo Denki University, Japan

Diamond-like carbon (DLC) has excellent properties such as high hardness, low coefficient of friction, and wear resistance. In order to use it as a protective film, it is important to improve the adhesion to the substrate. The adhesion of DLC films can be evaluated indirectly from the residual stress of that. However, the best non-destructive measurement method for it has not been established. Therefore, we propose a method for quantitatively evaluating the residual stress of DLC films by the laser photoelastic method. In this study, we prototyped the reflective photoelastic experimental apparatus that measure the residual stress of DLC films formed on substrates not transmitting a laser. It is a circular polarizing apparatus with Photoelastic Modulator (PEM) added, and we used an infrared He-Ne laser with a wavelength of $\lambda = 1150$ nm as the light source. To confirm that the apparatus works correctly, we report comparing the optical retardation of the DLC film measured by the reflective photoelastic experimental apparatus with that measured by the transmissive one. We used the SCHOTT D263T eco glass with a shape dimension of $4\times60\times0.55$ mm for the substrate of the DLC film. The film formation method is plasma CVD (plasma-enhanced chemical vapor deposition). A DLC film with a thickness of 670 nm was formed on a glass substrate at 200 ℃. Due to the difference in linear expansion coefficient between glass and DLC, the residual stress is generated in the DLC film at room temperature. Since the DLC film is
formed on the glass substrate, the optical retardation of the DLC film can be measured by the transmissive photoelastic experimental apparatus. In addition, that of the same specimen was measured by the reflective photoelastic experimental apparatus shown in Fig.1 (a). That configuration meets the following next conditions for accurate optical retardation measurement. They are, the angle of incidence of the laser on the specimen is as small as possible, and the number of beam splitters and mirrors between the polarizer and the analyzer is as small as possible. As a result, the optical retardation of the DLC film measured by the reflective photoelastic experimental apparatus was close to that measured by the transmissive one. For these, it was shown that the stress distribution measurement of DLC films by the reflective photoelastic experimental apparatus can be realized.

Fig.1  (a) Schematic of reflective photoelastic experimental apparatus, (b) Relationship between x coordinate and retardation. The area between the two broken lines indicates the measurement range of the specimen. The retardation measured by (a) is twice of the one measured by transmissive photoelastic experimental apparatus because the laser passes through the DLC film twice.

A56. 3-D Identification Method of Moving Object Using Sub Coil

Naoki KOHAMA1, Kohei TATEYAMA2, and Keiko WATANABE2
1 Major in Advanced Mechanical Engineering and Robotics, Ritsumeikan University, Japan
2 Department of Mechanical Engineering, Ritsumeikan University, Japan
E-mail: keikow@fc.ritsumei.ac.jp

It has been confirmed that when the object collides with a particulate material such as sand at high speed, it shows the complicated penetrating behavior. However, it is very difficult to identify the behavior of the object moving in the material such as sand due to visual limitations. In addition, high-time resolution is required to measure the continuous behavior of object. Therefore, a method for identifying the behavior of the object from the waveform of the induced electromotive force generated when the object loading with magnet passes through a single circular coil has been proposed. However, with a single circular coil, it is impossible to identify the trajectory of the object on a single circle with the same center as the coil due to the symmetry of the coil shape. Therefore, we proposed a method to identify the three-dimensional behavior of a moving object by newly installing two coils on the plane perpendicular to the circular coil and comparing the waveforms of the induced electromotive force. Here, in order to distinguish the coils, the coil that object pass through is called a “main coil”, and the coil that object doesn’t pass through the inside is called a “sub coil”. As an initial stage of this new method, it is necessary to
formulate the relationship between the object behaviors assuming meandering of the object and the induced electromotive force generated in the sub coil. In the previous study, we have formulated the relationship between the induced electromotive force generated in the sub coil when the object passes on the central axis of the sub coil. In this study, we formulated the relationship between the induced electromotive force generated in the sub coil when the object doesn’t pass on the central axis of the sub coil. In addition, a free fall experiment was conducted, and the validity of the theoretical formula was confirmed by comparing it with the induced electromotive force obtained from the experiment. Furthermore, the magnetic flux of the magnet was visualized using electromagnetic field analysis (Flux, Altair engineering), and the characteristics of the induced electromotive force were examined.

**Keywords:** Noncontact Measurement Method, Coils, Magnetic Flux, Induced Electromotive Force, Electromagnetic

A76. Research on solutions to improve the combustion efficiency of biofuel in Diesel engine by Simulation and Experiment

MAI Duc Nghia¹, NGUYEN Manh Cuong²
¹Faculty of Mechanical Engineering, Air Force Officer’s college, Nha Trang City, VietNam
Email: nghiamaiduc@gmail.com
²Faculty of Mechanical Engineering, Ho Chi Minh City University of Technology and Education, Thu Duc city, Ho Chi Minh City
Email: cuongnm@hcmute.edu.vn

Biofuels are currently being interested in development, especially to replace traditional fuels for diesel engines, because of their clean burning, environmental friendliness and renewables. However, because the chemical and physical properties of this fuel are different from that of traditional diesel fuel (DO), when used, the engine's fuel injection system needs to be adjusted to improve the formation process into the combustion mixture and increase power, especially for diesel engines with mechanical fuel injection systems. In order to limit the cost and time of experimentation, in this article, we present a simulation method using the CFD software Kiva - 3V, to determine the adjustment parameters (fuel injection pressure) when the diesel engine uses the mixture of diesel-coconut oil mixture (C15). The simulation results are verified with experimental results on the research engine (4CHE Yanmar) and show that, when the engine uses the C15 mixture, if the fuel injection pressure is adjusted, increases at the values of 215 bar and 225 bar, will have a capacity equivalent to the engine capacity using DO fuel at 205 bar (the manufacturer's standard injection pressure for traditional fuel).

**Keywords:** Kiva, diesel engine, diesel oil, coconut oil, injection pressure.

A77. Experimental investigation on Visualized Combustion Phenomena to evaluate the maximum blend when using Biodiesel fuel derived from rubber seed oil for Diesel engine

NGUYEN Manh Cuong
Faculty of Mechanical Engineering, Ho Chi Minh City University of Technology and Education, Thu Duc city, Ho Chi Minh City
Email: cuongnm@hcmute.edu.vn
Biodiesel is one of the promising renewables, alternative and environmentally friendly biofuels that can be used in diesel engine with little or no modification in the engine. Studying the combustion of biodiesel in diesel engine is one of the topics that many scientists are most concerned about. Optical visualization technique such as engine endoscopy is a very important tool for time resolved spatial combustion visualization and characterization. It provides valuable information about combustion in a production grade engine, which cannot be obtained by using any conventional techniques. In this study, engine endoscopy was done in a Mazda WL diesel engine with swirl Pre-chamber. Experimental engines have been using fueled with diesel (DO) and biodiesel blends (B15, B20, B25, B30). Combustion images were captured at different engine loads and different engine speeds to determine start of combustion (SoC), spatial soot distribution and spatial flame radiation temperatures. Results indicate that with increasing biodiesel content in the fuel, larger area of luminous flames in the combustion images was obtained for lower biodiesel blends. With increasing the proportion of biodiesel blends, the timing of fires starts to appear earlier at higher engine loads. It was also found that: It is possible to use biodiesel fuel with a maximum 20% (B20) blending ratio for Mazda WL diesel engine without modifying the structure.

**Keywords:** Biodiesel, Diesel engine, Engine endoscopy, Visualized, Combustion Phenomena.

6. SESSION MATERIAL ENGINEERING

A09. Change in Uniaxial and Biaxial Compressive Behavior with Alloy Composition of Metastable β-Type Titanium 10-18 mass% Molybdenum Alloys

Ichiro SHIMIZU1 and Yoshito TAKEMOTO2
1Faculty of Engineering, Okayama University of Science, Japan
2Graduate School of Natural Science and Technology, Okayama University, Japan
E-mail: shimizu@mech.ous.ac.jp

Titanium (Ti) alloys have special features such as high specific strength, excellent corrosion resistance, and biocompatibility. In particular, metastable β-titanium alloys obtained by solution treatment followed by quenching exhibit good cold formability thanks to a body-centered cubic crystal structure having a larger number of slip systems, so that they are expected to be applied for aircraft and medical devices. However, since the primary plastic deformation mechanism also changes with the amount of β-stabilizing element, their mechanical properties have not been fully understood especially under biaxial loading conditions.

In the past studies, it has been revealed that metastable Ti-14mass% Mo alloy exhibits large elongation with moderate strain hardening due to {332}<113> deformation twinning in the uniaxial tensile test. Understanding the influence of {332} twin on the plastic deformation behavior is the key to understand the mechanical characteristics of metastable β-titanium alloys. In the present study, the uniaxial and the biaxial compression tests were conducted on binary metastable titanium-molybdenum (Ti-Mo) alloys with Mo content from 10 to 18 mass% and the effect of twinning activity on compressive plastic deformation behavior was investigated.

Figure 1 shows true stress-true plastic strain curves in uniaxial compressions and equivalent stress-equivalent plastic strain curves in equi-biaxial compressions of Ti-10–18 Mo alloys. The clear Mo content dependency was found on the stress-strain relations. The electron microscopy revealed that the {332} twin was activated on Ti-10–16Mo alloys. Meanwhile, it was not on Ti18Mo alloy that denoted higher yield stress and lower strain hardening rate. It was also found that the area fraction of twins in equi-biaxial compression was lower than those in uniaxial
compression. Based on those results, the mechanism that induced changes of plastic deformation behavior with Mo contents in uniaxial and biaxial compressions was discussed with relation to the activation of deformation twinning.

A10. Evaluation of cyclic deformation behavior of hydrogel with different swelling ratios

Syunpei MORITA¹, Makoto UCHIDA¹, Yoshihisa KANEKO¹, Dai OKUMURA², Hiro TANAKA¹ and Shohei IDA⁴
¹Osaka City University
²Nagoya University
³Osaka University
⁴University of Shiga Prefecture
E-mail: m20ta032@zr.osaka-cu.ac.jp

Hydrogel contains a large amount of solvent such as water inside a three-dimensional network structure. The content of the solvent changes during the swelling and drying processes of the hydrogel. The external force applied during the processes affects the development of the solvent content. The mechanical properties of the gel significantly change depending on the solvent content. Currently, an application of hydrogels as biomaterials is expected and related research are progressing in the fields of polymer chemistry and medical science in order to effectively utilize hydrogels in various applications, it is important to appropriately fully understand the mechanical properties of materials.

The super elastic model is typically employed to explain the mechanical behavior of the hydrogel. The experimental results of the stress-strain curve until the large strain range and the change in the mechanical response by swelling ratio indicated that the inelastic deformation occurs for the as-prepared and swollen hydrogels. Therefore, the effects of the strain history and the swelling ratio on the nonlinear mechanical responses are investigated by the cyclic tensile test of the hydrogel specimen in this study. Tensile test specimen with different swelling rates were prepared by changing the swelling time under the free swelling process.

Uniaxial cyclic tensile tests were performed using the prepared specimen. Furthermore, the cyclic test with the increasing maximum displacement was performed, and the results were compared to those of the monotonic tensile test. The experimental results revealed the obvious change in the mechanical responses between first loading and following unloading processes in all hydrogel specimens. Meanwhile, the responses for the following reloading and unloading process coincided with that for the first unloading process. Furthermore, in the cyclic test with increasing
maximum tensile displacement, the difference in the response between loading and unloading processes was observed after the tensile displacement passed over the previous maximum tensile displacement. These results indicated that the unrecoverable residual deformation occurred as similar to the as-prepared rubber, and it reduced the slope of the stress-strain curve of the hydrogel. Although the strength of the hydrogel decreased with increasing swelling ratio the swelling ratio did not affect the residual strain.

**Keywords**: hydrogel, viscosity, swelling ratio, cyclic deformation, elastic deformation

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**A16. Mechanical Properties in Maraging Steel at Over-Aged Treatment**

Ryohei ICHIMIYA¹, Akihiro TAKAHASHI¹, Naoyuki YAMAMOTO¹, Toshinobu TOYOHIRO¹, Hiromi MIURA² and Masakazu KOBAYASHI²  
¹Department of Mechanical Engineering, National Institute of Technology (KOSEN), Miyakonojo College, Japan  
²Department of Mechanical Engineering Toyohashi University of Technology, Japan  
Email: akihiro@cc.miyakonojo-nct.ac.jp

The aim of this study is to present the results of an examination whose goal was to study the characteristics of tensile strength and its fracture in over-aged maraging steel. The used material was a commercial maraging steel with composition of Fe- 18 mass % Ni with low carbon content with bar in diameter of 9 mm produced by Hitachi Metals. The cut bar samples were solution-treated at 1123 K for 5.4 ks, and then cooled in air in accordance with a previous study of other researcher. They were subsequently aging treated at 753 K for several periods: 150 ks, 280 ks, 550ks and 1100 ks. Observation of microstructural evolution, Vickers hardness test and tensile examination were conducted at several aging treatments. 2154 MPa in over-aged tensile strength at 753 K - 1100 ks was 8 % decreased than that at peak-aged at 753 K - 150 ks (Fig.1). Dimple fracture was observed at all samples (see Fig.2). It was suggested that overageing caused change in appearance precipitation particles and other phase formation during heat treatment, results in entire martensite to austenite phase.

![Fig.1 Tensile stress-strain curves](image-url)
Microstructural observation and tensile test were carried out to examine relationship between tensile property and fracture morphology of a latewood in growth direction in Japanese cedar called Obi-sugi. Fracture behavior for the latewood specimen was recognized from tensile stress-strain curve and embrittlement fracture surface. Two kinds of fracture mode of the principal stress fracture and the shear fracture were confirmed. As results Weibull statistics analysis, expected value of tensile strength, $\bar{\sigma} = 180$ MPa in principal stress fracture mode was approximately 37% increased than that in shear fracture mode (Fig.1 and Table 1). Two fracture mechanisms in latewood were described and discussed based on the failure observation results by scanning electron microscope (Fig.2).

### Table 1  Weibull analysis results

<table>
<thead>
<tr>
<th>Tensile strength, $\sigma_0$ (MPa)</th>
<th>(a)Principal stress fracture</th>
<th>(b)Shear fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weibull analysis</td>
<td>$\sigma_0$</td>
<td>180</td>
</tr>
<tr>
<td>m value</td>
<td>4.2</td>
<td>4.9</td>
</tr>
<tr>
<td>Correlation coefficients, R</td>
<td>0.88</td>
<td>0.98</td>
</tr>
</tbody>
</table>

**Fig.1**  Weibull plot for the tensile strength

**Fig.2**  Fracture surface of the peak aged and the over aged sample
Recently, magnesium (Mg) alloys have been extensively used in the vehicle and aerospace field as well as in the other structural applications, because of their better density and higher specific modulus and strength than several metallic materials. Demand for Mg alloys is increasing in many industrial sectors. However, the research on the mechanical property of Mg alloys at cryogenic temperature have not been rarely reported. The aims of this study are to investigate the quasi-static tensile mechanical property and fracture behavior of the hot-extruded and the multi directional forged (MDFed) AZ31Mg alloy at two testing temperatures of 77K and room temperature. Fig.1 shows the microstructures at each MDFed samples. As the number of MDF pass increased, the grains were refined, and the average grain size was decreased from 16.7 μm for initial sample (Fig.1 (a)) until 1.0 μm for 5th passed sample (Fig.1 (c)). Fig.2 shows tensile stress-strain curve at room temperature and 77 K. A wide difference in the curves between RT and 77 K was the existence of serration which stress drops and strain jumps. It was suggested that twin deformation during tensile examination was a main factor for the serration behavior at cryogenic testing temperature.
A19. Ductile Fracture Behavior and Stress Triaxiality in AZ31 Magnesium Alloy

Keita HIROIKE, Ryota KAWANO, Akihiro TAKAHASHI, Naoyuki YAMAMOTO, Toshinobu TOYOHIRO, Masakazu KOBAYASHI and Hiromi MIURA

1Department of Mechanical Engineering, National Institute of Technology (KOSEN), Miyakonojo College, Japan
2Department of Mechanical Engineering Toyohashi University of Technology, Japan
Email: akihiro@cc.miyakonojo-nct.ac.jp

Fundamental ductile fracture behavior with notched in Magnesium (Mg) system alloys have not been fully investigated in the past decade. To acquire high demand and manufacturing high performance components for Mg alloys, the material failure and large cracks should be strictly restrained in operation. Therefore, it is important for material designers to deeply understand the fracture characteristics with intense notched specimen of Mg alloys. There are few reports on the influence of notched parameters and stress triaxiality on the tensile ductile fracture behaviors for the Mg alloys. In this study, the tensile test of notched round specimen within the stress triaxiality of 0.33 to 1.39 were carried out to confirm the basic notched property of mechanical strength and ductile fracture behavior of a hot-extruded AZ31 Mg alloy at quasistatic strain rate and at room temperature. The tensile strength, $\sigma_B$ and yield strength, $\sigma_y$ increased with increasing stress triaxiality as shown in Fig.1. Fracture circumference strain was decreasing as triaxial stress state gone up. Entire fracture surfaces on the notched specimen of $R=12$ and smooth specimen were dominantly ductile dimple fracture type with weak shear deformation. Fracture surface of $R=1$ of lower stress triaxiality showed flat failed portion like quasi-cleavage fracture and it was appeared that many quasi-cleavage facets and small tearing ridges (see Fig.2).
A21. High Cycle Fatigue Strength and Residual Stress of Punched Fe-Si Steel Sheets

Takumi Nagao¹, Hiroto Ueno¹, Koichi Akita¹, Takashi Abe² and Hiromitsu Watanabe²

¹Dept. of Mechanical Systems Engineering, Tokyo City University, Japan
²Meidensha Corporation, Japan

Fe-Si electrical steel sheet is a soft magnetic material and widely used in electric motor cores. In recent years, the mechanical loads subjected on the material during operation is being higher due to the demand for the higher energy efficient motors. Therefore, it becomes important to clarify the fatigue properties of the material. The punching process is generally used for cutting out laminates from the steel sheet because it enables high productivity. However, the punching process may introduce various defects into the material such as residual stresses, micro cracks, surface roughness, and so on. These defects can affect fatigue strength, but the details of the fatigue mechanism have not yet been clarified.

The purpose of this study is to clarify the effect of defects induced by punching process on the fatigue strength of electrical steel sheet. The material used in this study was a high-strength type non-oriented electric steel sheet with a thickness of 0.5 mm. Fatigue specimens were punched out from the steel sheet. The clearance between the die and punch was set at 5 %, 7 % and 9 % in terms of the sheet thickness ratio. Wire cut electric discharge machining (WEDM) was also used to cut-out the fatigue specimens for comparison. Residual stresses of the punched surface were measured using an X-ray diffraction method.

High tensile residual stresses were introduced in the cut surface by punching process and they became higher with smaller die-punch clearance. The tensile residual stress especially on the tensile fracture zone was higher than that on the shear zone of cut surface. Residual stresses on the WEDM machined surface were also tensile but they were smaller than that of punched surface. During fatigue loading, residual stresses of the punched surface were decreased but relatively higher tensile residual stress about 300-400 MPa was kept until final fatigue fracture. The fatigue strength of punched specimens was clearly lower than that of WEDM specimens and slightly decreased as the die-punch clearance was smaller, that is, as the tensile residual stress was higher. Almost all of fatigue cracks of punched specimens were initiated near the tensile fracture zone or the boundary of shear zone and tensile fracture zone. Tensile fracture zone had larger surface roughness and higher tensile residual stress compared with the shear zone and the WEDM machined surface, and sometimes microcracks which were generated by punching process were observed at the boundary. It is considered that these defects on the punched surface: tensile residual stresses, surface roughness and microcracks may reduce the fatigue strength.
A29. Material Properties Degradation of Radiation Shielding Lead Glasses by Laser Irradiation

Takashi WAKUI1, Kazuhiko YAMAZAKI2, Makoto TESHIGAWARA1 and Masatoshi FUTAKAWA1
1J-PARC Center, Japan Atomic Energy Agency, Japan
2Graduate School of Science and Engineering, Ibaraki University, Japan
E-mail: wakui.takashi@jaea.go.jp

The highly radioactive components in spallation neutron source in MLF/J-PARC should be classified and cut partly for the backend treatment taking radioactive levels into account. Although laser-cutting technique is prospective for cutting them remotely, it is difficult to mitigate the secondary contamination due to the spattering phenomena, etc. caused by the rapid high intense thermal loading. One of ideas to apply the laser cutting technique for radioactive components is to surround objects and localize the contamination. Laser will be injected through a sort of transparent glass to them.

In general, the lead glass has a radiation shielding performance and a high visible light transmittance, and then has been used in various fields with radiation utilization such as industrial, medical and agricultural fields. If the lead glass can be used as a laser transmissive window, highly radiated materials in a closed space can be cut by emitting the laser from the outside of the window and products induced by cutting can be trapped in the closed space. However, it was reported that optical characteristics change and coloring phenomena of the radiation shielding lead glass by X-ray irradiation. So that, the damage caused by a high-power laser irradiation was investigated in detail from the viewpoint of material properties degradation in micro-scale region.

In this study, pulsed Nd:YAG laser (wavelength of 1064 nm, pulse width of 1.5 ms, spot diameter of 0.3 mm) is applied to radiation shielding glasses with different lead content: PbO-55 wt% and 71 wt%. Although no change of the lead-free glass was observed, laser damage is observed on the surface of lead glasses as shown in Fig.1. In the case of 50 pulses on the specimen with higher lead content, large cracks occurred. In order that the change of mechanical properties by the laser irradiation was investigated in the micro-scale region for each glass, young’s modulus, Vickers hardness and fracture toughness were estimated based on micro-indentation load and depth curves and crack length obtained by micro-indentation tests with Vickers indenter. Furthermore, material contents in the constitutive equation of each glass were identified by using an inverse analysis with Kalman’s filter on load and depth curves measured by using a spherical indenter.

![Fig. 1 Photographs of damages on lead glass surfaces: (a), (b) specimen with lower lead content (PbO-55 wt%), (c), (d) specimen with higher lead content (PbO-71 wt%).](image)
A39. Delamination Behavior in Compression Bending Test of Organic Semiconductor Device

Toshiro KOBAYASHI1, Shigeru NAGASAWA2, Hideaki FURUMOTO3, Ion GRUESCU4, Akinobu YAMAGUCHI5, and Yuichi UTSUMI5

1Department of Electronics & Control Engineering, National Institute of Technology, Tsuyama College, Japan.
2Department of Mechanical Engineering, Nagaoka University of Technology, Japan
3Department of Industrial Engineering, Hiroshima Kokusai Gakuin University, Japan.
4Department GMP, Institute Universitaire de Technologie A de Lille, France
5Laboratory of Advanced Science and Technology for Industry, University of Hyogo, Japan

E-mail: t-koba@tsuyama-ct.ac.jp

In the present study, experimental study was conducted on delamination caused in the compression bending test of organic semiconductor devices, and the effect of layer structure, bending strain, and bending frequency on delaminating occurrence and progression was investigated and discussed. In order to improve the flexibility of the flexible OLED, the authors have mainly conducted a tensile test and investigated the delamination behavior due to crack susceptibility and compressive strain of constituent materials of organic semiconductor elements. In this study, specimens such as PEN substrate / Alq / MgAg, PEN substrate / PEDOT / Alq / MgAg were prepared using wet process and vacuum process and subjected to compression bending test.

As a result, the number of stripes due to delamination showed a constant value or a decreasing tendency when the compressive strain was 1% or more, and it was found that the maximum width of the stripes tended to increase although the minimum width of the stripes was not greatly changed. This is considered to be due to the fact that the width of the fringes initially generated increases with the increase in compressive strain and merges with the adjacent stripes. Furthermore, it has been suggested that the adhesion of the film could be semi-quantitatively evaluated by the compression bending test, in the case of the same layer configuration, since it is presumed that delamination did not occur until the high compressive stress as the number of stripes increased, from the basic equation of buckling.

Fig. 1 Compression bending test. (a) equipment, (b) an example of the stripes due to delamination.
Membrane materials utilizing high-strength fibers have been recently researched, developed, applied to various fields (e.g., aerospace) because of their flexibility and lightweight. However, fibrous materials, especially woven ones, exhibit special behaviors because of their complex structures, which limits their design. In addition, since the strength of polymer materials generally decreases due to UV degradation, it is important to clarify how the failure mechanism changes due to UV degradation. In this study, we used acoustic emission (AE) method to clarify the fracture mechanism of woven fabrics, and evaluated how the fracture mechanism of fabrics degraded by UV changes. The fracture mechanism of the woven Kevlar fabric was first estimated by monitoring its tensile test by using the AE method. Two different AE waveforms were detected during the tensile tests. Experimental simulation was next conducted. And it was found that the two type waveforms shown in Fig. 1 were caused by fiber breakage and fiber friction, respectively. Fracture mechanism of woven Kevlar fabric with UV degradation was then investigated. The fracture strength and Young's modulus of the UV-exposed specimens decreased by about 90% and 85%, respectively, compared with those before the 213-day UV exposure test. This decrease in strength is thought to be caused by the stress concentration on the surface of the fiber due to the unevenness caused by the scission of molecular chain by UV irradiation. Furthermore, tensile tests of the UV-degraded fabrics were monitored by the AE method, and it was found that the strength of the UV-degraded fabrics decreased due to an increase in the friction between the constituent yarns and an increase in the number of fiber breaks in the constituent yarns.

Fig. 1 Two type AE waveform and their frequency spectra.
7. SESSION SOLID MECHANICS

A11. Effect of Tensile strain rate on Mechanical Response of Polyamide with Different Molecular Chain Structures

Toyoshi YOSHIDA, Tomoya NAKANE, Makoto UCHIDA and Yoshihisa KANEKO1
Graduate School of Engineering, Osaka City University, Japan
Email: d20ta551@ab.osaka-cu.ac.jp

Polyamide (hereafter, PA) is a semi-crystalline polymer in which repeating units of amide groups (-NHCO-) is contained in a molecular chain. PA shows excellent mechanical properties by intermolecular hydrogen bond between hydrogen atom and oxygen atom of amide groups between neighboring molecular chains. The hydrogen bond densities and existence of aromatic ring in the molecular chain affect the rigidity of the molecular chain. In addition, the nonlinear mechanical behavior of PA is characterized by the debonding and rebonding of intermolecular hydrogen bond. Predicting the mechanical properties of PAs having different molecular structures is very important to the research and development of new materials such as biobased PA.

In this study, the effects of the density of amide group, crystallinity, and the aromatic ring of the molecular chain were investigated by uniaxial tensile tests of commercial PA, PA11, PA610, amorphous PA6, semi-crystalline PA6, and PA-MXD10.

Comparison of mechanical responses of PA11, PA610 and PA6 clarified that Young’s modulus and the maximum stress increase with the density of the amide group in the molecular chains. When PA has a large density of the amide group in the molecular chain, the density of the intermolecular hydrogen bonds increases. It results in the improvement of rigidity and strength of PA.

The tensile stress typically increases with the tensile strain rate due to the viscosity. Such a strain rate dependency decreased for PA with smaller crystallinity. Although the rigidity and strength increase with the crystallinity, the material is embrittled for the PA with much higher crystallinity.

As compared to PA11, a rapid decrease in stress was observed in PA6 and PA-MXD10 at deformation stage after the maximum stress. In this stage, the strain field, which was evaluated by digital image correlation method, showed that a high deformation concentration occurred accompanying the rapid decrease in the stress for PA6 and PA-MXD10.

From these results, although the increase in the density of the intermolecular hydrogen bonds and the introduction of the aromatic rings in the molecular chain improved the rigidity and yielding stress of the PA, the higher strain concentration occurred after the maximum stress. This can be explained by the debonding of the intermolecular hydrogen bonds, which is characterized by the density of the amide group and the presence of the aromatic ring. On the other hand, the effect of the crystallinity is relatively small.

![Fig. 1 Nominal-Stress Nominal-Strain Curves](image_url)

(a) PA11 (crystallinity 13%)
(b) PA6 (crystallinity 18%)
A12. Effects of Grain and Specimen Sizes on Micro- and Macroscopic Non-uniform Deformation of Polycrystalline Copper

Kensho TSUTSUMI¹, Makoto UCHIDA², Masashi SAKAMOTO³ and Yoshihisa KANEKO²
¹Graduate School of Engineering, Osaka City University, Japan
²Faculty of Engineering, Osaka City University, Japan
³Nippon Steel Corporation, Japan
E-mail: m20ta020@hb.osaka-cu.ac.jp

With an increase in the relative grain size to the macrostructure, the collective behavior of the crystal grains will affect the macroscopic deformation field. Experimental quantification and theoretical modeling of the development of such a micro- to macroscopic nonuniform deformation are important to optimize the manufacturing process of the miniaturized metal parts in the various small-sized devices. Recently, strain fields in various materials have been accurately measured using the digital image correlation (DIC) method for a wide range of scales.

To investigate the relative size effect on the mechanical behavior of the polycrystalline material, the interaction between the microstructure-induced non-uniform deformation and the macroscopic boundary condition-induced non-uniform deformation of polycrystalline copper was evaluated from experimental and numerical studies. Effects of the macroscopic boundary condition and grain size on the strain field of the specimen were evaluated using different size specimens obtained from different thermal treatment conditions. The development of the strain distribution was measured by DIC. A nonuniform deformation depending on the macroscopic boundary condition was observed in the specimen with smaller grains, whereas the microscopic non-uniform deformation affected the macroscopic nonuniform deformation in the specimen with larger grains.

The full-scale crystalline plasticity finite element method simulation with similar conditions to the experiment was then performed. The local deformation bands, in which the length and width depended on the grain size, occurred in the polycrystalline specimen, and it affected the non-uniform deformation caused by the macroscopic boundary condition. In order to discuss the relative specimen size effect, the plastic strain was divided into the local plastic strain and the nonlocal plastic strain. Both the experimental and simulation results clarified that the nonlocal plastic strain gradient evaluated in the finite volume region increased with region averaged stress. From these results, we proposed the constitutive equation for the plastic strain as the function of local stress and finite volume averaged stress.

A20. Effect of Convolution Shape on Strength for Flexible Metal Bellows Subjected to Internal Pressure

Katsuya Fujimoto¹,², Hiroyuki Fujiki², Masashi Daimaruya² and Hiroyuki Yamada³
¹ TOFLE Co., Inc. 1-6-16 Honmachi, Chuo-ku, Osaka 541-0053, Japan
² Dep. of Mech. Sys. Eng., Muroran Institute of Technology, Japan
³ Dept. of Mech. Eng., National Defense Academy, Japan
E-mail: fujimoto@tofle.com

A hydrogen stations is a facility that supplies hydrogen to fuel cell vehicles (FCV). Most of the current flexible hoses for dispensers suppling the high-pressure hydrogen gas to FCV are made of rubber and resin-based materials. They are required to have the characteristics of resistance to permeation of the gas, and to inhibit the internal fractures known as blisters caused by hydrogen gas decompression. If the rubber and resin-based materials can be replaced with metal materials, those difficulties may be resolved. However, another problem called hydrogen embrittlement of
metal materials will arise when using metal materials. In addition, the metal tubes to make up the hoses must be machined as a bellows in order to give them flexibility.

In this study the relationship between internal pressure strength of flexible metal bellows and their convolution shapes is investigated by CAE analyses and the corresponding experiments (Fig. 1). Two kinds of stainless steels with high Ni equivalent are used for flexible tubing. Properties of high Ni equivalent in those stainless steels mean to suppress hydrogen embrittlement. First, tensile tests of the tubular specimens of those stainless steels are carried out at temperatures ranging from 233K to 343K, and then CAE analyses are performed on the basis of the obtained stress-strain diagrams. Second, a U-shaped bellows and a bellows made by compressing it in the axial direction are fabricated, and then both the internal pressure strengths are compared. It is a remarkable result that the larger the degree of compression in the axial direction of bellows, namely the smaller the convolution pitch of bellows, the larger the internal pressure strength.

![Fig. 1 Typical vertical split of metal bellows due to internal pressure.](image)

**Key words**: Hydrogen station, Fuel cell vehicles, Hydrogen gas dispenser, Metal U-shaped bellows, Axially compressed bellows

### A25. Effects of Friction Coefficient on the Plastic Behavior of Granule

Thanh-Trung VO\(^1\), Dinh Minh TRAN\(^2\)

\(^1\)Bridge and Road Department, Danang Architecture University, Danang City, Vietnam

\(^2\)The University of Danang - University of Science and Technology, VietNam

E-mail: trungvt@dau.edu.vn

We numerically investigate the effects of coefficient of friction of primary particles on the plastic properties and texture of wet granules composed of solid particles by using molecular dynamics simulations, subjected to diametrical compression test between two platens. The numerical algorithm with a capillary cohesion law characterized by the cohesive force is as an explicit function of the gap between primary particles and liquid-vapor surface tension, and the liquid content is mainly accounted for a rupture distance with the binding liquid assumed to be distributed homogeneously inside wet agglomerates. We find that due to the rearrangement of wet primary particles during the compression, the granule shows the plastic behavior which clearly presents in the stage of the plateau strength. The compressive strength of wet agglomerates reaches the plateau peak before failure due to the irreversible loss of wet contacts between primary particles. By a well-defined characteristic cohesive stress, the plastic threshold of the agglomerates increases proportionally to the friction coefficient, and as a nearly linear function of the amount of binding liquid up to the debonding distance. The results also show the dependence of the friction coefficient on the microstructure of wet agglomerates in the expression of the texture parameters such as wet coordination number and packing fraction.
A45. Effect of Local Buckling in Autofrettage Process on the Fatigue Behavior of the Liner in Al/CFRP Composite Pressure Vessels

Xuan Cuong NGUYEN\textsuperscript{1,2}, Yoshio ARAI\textsuperscript{1}, Wakako ARAKI\textsuperscript{1} and Noriyasu YAMADA\textsuperscript{1}

\textsuperscript{1}Graduate School of Science and Engineering, Saitama University, Japan
\textsuperscript{2}Faculty of Mechanical Engineering, National University of Civil Engineering, Vietnam

The liner buckling is one of the failure mechanisms in Al/CFRP (Carbon Fiber Reinforced Plastic) composite pressure vessels, leads to not only decreasing the load-carrying capacity but also can affect the fatigue life of the vessel. In this simulation analysis, an Al/CFRP composite vessel was modeled with interfacial delamination between the aluminum liner and CFRP layer to evaluate the effect of buckling during the autofrettage process on the deformation, stress components, and plastic strain of the liner when repeated pressure applied.

The cylindrical vessel consists of the aluminum liner overwrapped by FRP layers with the liner thickness of 1.3 mm and the total thickness of layers is 2.58 mm. The liner used in this research was 6061-T6 aluminum alloy. The inner diameter of the liner is 96.4 mm and 350 mm in length corresponding to 2.1 L in the volume of the vessel. The composite layer including two CFRP layers and two Glass Fiber Reinforced Plastic (GFRP) layers stuck together by the filament winding method. The matrix material used in this study is epoxy resin. A one-sixth finite element model of the cylindrical part of the vessel was modeled in this analysis. A rectangular shape of the de-bonding area was embedded in the interface between the liner and CFRP layer. The delaminated area accounts for 25 percent of the entire interface and was located at the center of the segment.

In the simulation method, linear buckling analysis of the liner model with an external pressure assigned on the delamination region was run to achieve the eigenmodes and eigenvalues. These results play a role as the input parameters. An imperfection was also added by a percentage of the liner thickness to analyze the non-linear buckling of the vessel which was considered as the autofrettage process and followed by the cyclic load analysis. The pressure amplitude in the autofrettage process was reduced by nearly half in the cyclic pressure step.
The autofrettage process includes the loading and unloading process. In the loading process, the vessel is applied proper internal pressure and then completely unloaded to obtain the desired compressive stress in the liner. It is assumed that the buckling occurs due to the residual compressive stress in the unloading stage. As a result, the behavior of the liner is affected when applying the cyclic pressure to the vessel.

The equivalent plastic strains of the liner in case of buckling are inhomogeneous in each process from the onset of loading to complete unloading, whilst these values remain consistently if buckling does not occur. Furthermore, this strain has a greater value with consideration of buckling when the vessel is subjected to cyclic pressure and its amplitude also changes slightly during the cyclic loading and unloading process. In general, the displacements and stresses in both cases with and without buckling show a significant variation during repeated loading processes. However, with consideration of buckling, these values fluctuate considerably in comparison with the almost unchanged values at each stage of the cyclic pressure process in the case without being buckled. Due to local buckling, the fluctuation of displacements and stress components of the liner present higher values at the de-bonding region during the cyclic pressure.

**Keywords:** Buckling, Al/CFRP composite pressure vessel, Autofrettage process, Cyclic pressure, De-bonding area.

**A55. Measurement of Stress Waves Passing Through Glass Beads Using SHB the Test Equipment**

Yosuke ARAI¹, Kohei TATEYAMA², and Keiko WATANABE²

¹ Major in Advanced Mechanical Engineering and Robotics, Ritsumeikan University, Japan  
² Department of Mechanical Engineering, Ritsumeikan University, Japan  
E-mail: keikow@fc.ritsumei.ac.jp

To understand the mechanical properties of granular materials at high strain rates, it is necessary to understand stress wave propagation behavior between each particle (force-chain) in granular materials. Granular materials have many unique parameters such as particle size, packing density, and particle shape. For many granular materials such as sand, granular parameters are randomly distributed and cannot be controlled. Therefore, it is difficult to understand the effect of each parameter on stress wave propagation behavior. On the other hand, particle shape of glass beads is circular and constant. Only the effect of packing density on stress wave propagation behavior can be measured by filling glass beads which have constant particle size. Therefore, glass beads were used in this study to control granular parameters. The purpose of this study was to measure the stress waves through glass beads by using the SplitHopkinson Bar (SHB) test equipment and to clarify the effect of packing density on stress wave propagation behavior. The glass beads used in this study consisted of SiO2, and particle sizes of them were 200 to 300 µm. As a specimen, these glass beads were filled in a cylindrical container having a diameter of 30 mm and a height of 15 mm. To examine the effect of packing density on stress wave propagation behavior, three types of packing density (1.4×10³ kg/m³, 1.5×10³ kg/m³, and 1.6×10³ kg/m³) were prepared. The SHB test equipment was used to apply stress waves to the specimen. Generally, the SHB test is applied to solid materials but was applied to granular materials in this study. The test equipment consisted of a striker, an incident bar, the specimen, and a transmitted bar. The lengths of these bars were 750 mm, 2000 mm, and 1000 mm, respectively. The stress waves generated when the launched striker had collided with the incident bar passed through the incident bar, the specimen, and the transmitted bar. This test was able to measure indirectly the stress waves transmitted through the specimen from the strains of the incident bar and the transmitted bar when
the stress waves passed. This equipment is very useful for granular materials whose strain cannot be measured directly by strain gauges. As a result, it was possible to measure the incident stress waves, reflected stress waves, and transmitted stress waves by the SHB test. Stress wave velocity and attenuation in glass beads were confirmed. In addition, the results clarified the effect of packing density on stress wave propagation behavior in glass beads.

**Keywords:** Granular Materials, Split-Hopkinson Bar Method, Stress Waves, Packing Density, Force-chain (five words)

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**8. SESSION SOUND AND VIBRATION**

**A37. Rotary Elastomer Particle Damper: Does Particle Type and Shape Matters?**

Allah RAKHIO¹, Yasushi IDO¹, Yuhiro IWAMOTO¹ and Atsushi TOYOUCHI²

¹ Department of Electrical and Mechanical Engineering, Nagoya Institute of Technology, Gokiso-cho, Showa-ku, Nagoya 466-8555, Japan,

² KYB Corporation, 2548 Dota, Kani-shi, Gifu, 509-0298, Japan

E-mail: r.allah.778@stn.nitech.ac.jp

In this paper, the damper torque properties of a rotary elastomer particle damper are analyzed. The effects of packing fraction, rotational speed, type of particles and shape of the particles on damper torque are investigated. Numerical simulation is conducted to understand the behavior of particles inside the rotary elastomer particle damper. Particle dampers controls the vibration of any mechanical system by dissipating the kinetic energy; kinetic energy can be dissipated in two ways in a particle damper, one by friction between particle to particle and particle to wall of the damper and second is collisions between particle to particle and particle to wall of the damper. In this article to investigate the behavior of particles in the rotary elastomer particle damper, the simulation based on discrete element method (DEM) was performed. The research is based on investigation of effect of packing faction, rotational speed, and type of elastomer particle as well as shape of elastomer particle on damping characteristics of a rotary elastomer particle damper.

![Fig. 1 The torque versus rotational speed cure, using 3 mm particles made of TSE3566 and TSE345](image)

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1. Effect of type of elastomer particles on damper torque Particles made from TSE3466 and TSE3453 are used in this research. TSE3466 and TSE3453 are silicon rubbers. From the Fig. 1, it is concluded that particles made from TSE3466 are capable of producing higher damper torque than particles made from TSE3453. TSE3466 particles produced damper torque than particles made from TSE3453; this is because higher tensile strength and hardness of TSE3466 are higher than TSE3453.

Figure 2 shows the torque vs. packing fraction graph at rotational speed of 120 rpm by varying the packing fraction and compare the experimental results with simulation results. The tendency of the simulation results is the same as the experimental results.

![Fig. 2 Experimental and simulation results of the torque versus packing fraction curve using elastomer particles of 3 mm diameter (TSE3466). The rotational speed is 120 rpm.](image)

A38. Research on Aerodynamic Noise Reduction Technologies Focusing on Sound Transmission Loss of Object Surface

Koki SHIGE, Miyu OKUNO, Reon NISHIKAWA and Osamu TERASHIMA
Department of Mechanical System Engineering, Toyama Prefectural University, Japan

Currently, we use air conditioners to maintain rooms at comfortable temperature. However, the aerodynamic noise from air conditioners is unpleasant. In some cases, noise induces stress and decreases labor productivity. Therefore, there is a need to reduce aerodynamic noise, but existing passive noise control techniques do not significantly reduce aerodynamic noise in general. Therefore, we attempted to reduce the aerodynamic noise generated by objects in a flow using a porous material that enables sound transmission but not fluid flow. It was found that the application of the porous material on the longitudinal surface of a rectangular cylinder, which consisted of four plates with a thickness of 3mm and an aspect ratio of 1:2 each, could reduce aerodynamic noise. The lower the flow velocity, the more significant the aerodynamic noise reduction effect obtained. Moreover, slight noise reduction effect was observed, even when the aspect ratio of the rectangular plates was 1:3 and 1:4. However, the higher the aspect ratio, the lower the noise reduction effect, owing to the existence of the re-attachment region on the rectangular cylinder surface in these cases. Finally, the sound transmission loss characteristics of the applied porous material affected the noise reduction effect.
A66. Absorption of the Longitudinal and Vertical Vibration by the Dynamic Absorber Using Elliptical Magneto Rheological Elastomer

Takumi NAITO$^1$ and Osamu TERASHIMA$^2$

$^1$Department of Mechanical Systems Engineering, Toyama Prefectural University, Japan
$^2$Faculty of Mechanical Systems Engineering, Toyama Prefectural University, Japan

In our previous study, a broad band frequency tunable dynamic absorber was designed and fabricated based on the primary design principle of a mass damper. A magneto-rheological elastomer (MRE) that can change the relative stiffness when an external magnetic field is applied was used to control the natural frequency of the movable mass of the absorber. A coil to generate the magnetic field was also used as a movable mass to decrease the total weight and to create a constant closed loop of the magnetic force. The hammer impact test results showed that the present absorber could change its natural frequency and had an almost constant damping ratio. In addition, the natural frequency and damping ratio of the absorber could be changed by adjusting the mixing ratio of materials to prepare MRE. Further, experimental results of vibration absorbing of a flat plate and a vibrating part of the commercial vehicle showed that the vibrational acceleration could be reduced automatically in the frequency range from 50 to 150 Hz with simple techniques to determine the strength of the magnetic field to be applied to the MRE by controlling the electric current applied to the coil (AEM, 2020).

However, our previous absorber only reduces the vibration for the vertical direction. Therefore, we could not reduce both vibrations for the vertical and longitudinal direction caused by the engine of the vehicle. In the present study, for the purpose of further improving of the absorber to reduce the vibration effectively, the absorber that can reduce the vibration both in the vertical and longitudinal direction of the vibrating objective was studied. As a result of changing the shape of MRE used in the previous absorber from a circular shape one to an elliptical shape one, the vibration in both the lateral and vertical direction of the vibrating objective could be reduced with applying the optimum current to the coil.

Fig. 1 Schematic view of (a) previous dynamic absorber and (b) present one.

9. SESSION VISUALIZATION AND IMAGE PROCESSING

A22. Study on Decontamination Effect of Shot Blasting and Barrel Polishing system

Seigo KAI$^1$, Ryo IKEDA$^1$, Hideharu TAKAHASHI$^1$, Hayato TANIGUCHI$^2$, Akihiko KAWASHIMA$^2$, Hiroshi TAKAHASHI$^3$, Keisuke JINZA$^4$, and Hiroshige KIKURA$^1$
Decommissioning is one of the important topics in the nuclear field because many nuclear power facilities in Japan have been decided to be decommissioned and the number of nuclear facilities to be decommissioned will be increasing worldwide. The decommissioning of a nuclear power plant involves various processes, such as investigation of the contamination inside the buildings, decontamination, dismantling of the buildings and surrounding facilities, and disposal of waste. In the piping system of nuclear reactors, CRUD (The Chalk River Unidentified Deposit) are released by erosion and corrosion in the process of operation, and they become radioactive in the reactor and are adsorbed to the piping again. CRUD is main causes of pipe contamination. The separation and decontamination of CRUD is an important process to reduce the radiation exposure of workers and to reduce the amount of low-level waste (LLW). A decontamination machine that combines shot blasting and barrel polishing has been developed and by using this machine, the radioactivity of contaminated pipe is decreased in hot test. However, the decontamination process using particle abrasives has many unanswered questions due to its complex phenomena. It is essential to elucidate the decontamination mechanism in detail to improve the decontamination efficiency, especially for objects with complex shapes such as small-diameter pipes.

In this study, we separated the decontamination mechanisms of the shot blast and barrel polishers. Then we conducted simulated decontamination tests using simulated decontaminants and visualization tests of the decontamination process in each machine to clarify the decontamination effect and mechanism in each process. Figure 1 show one example of particles emitted by a blast machine at 30 m/s captured by high speed camera. Blast polishing was found to be superior for decontamination by particle impact. In addition, the particles projected by blasting showed complex behavior inside the pipe. On the other hand, since the decontamination area inside the pipe was limited, the barrel mechanism was considered to assist the blasting mechanism.

Fig. 1 Blasting particles Captured image by High-Speed Camera (Particle shot speed 30 m/s)

Keywords: Decontamination, Shot Blasting, Barrel Polishing, CRUD, Decommission
Air duster is widely used to remove dust and mist from objects in industrial field. It is often attached various additional nozzles. There is a few research shown the role of the nozzle. The contribution for work efficiency of it has been also unclear. The aim of this study is to clarify the influence of the nozzle to air duster with the three-components velocity measurement by using stereo PIV (Particle Image Velocimetry).

A nozzle with double structure is attached on the tip of air duster in this experiment. When the compressed air by a compressor is exited at the tip of nozzle, its inner component of the additional nozzle rotates by flow in it. The two high-speed cameras capture simultaneously the image in the cross section of the flow field. The components of velocity field are obtained by stereo PIV for the captured images. The vorticity is also calculated from distribution of velocity.

Distributions of both the mean velocity and mean vorticity at 150 mm from the edge of nozzle are shown in figure 1. In this experiment, the compressed air is set 0.2 MPa and flow rate is about 100 L/min. The vector corresponds to the velocity of \( u \) and \( v \) and the color shows the velocity of \( w \) in downstream direction, respectively. The distribution of velocity corresponds to motion of nozzle as counterclockwise rotation. The swirl flow appears small near the center of nozzle and it grows around of center of nozzle. The distribution of vorticity is divided into two areas as the counterclockwise (negative, blue) and clockwise (positive, yellow and red). It is considered that involution of air to the center of the stream occurs on the area of positive vorticity. Thus, air can be sucked into the area of the flow with large velocity.

![Image](image1.png)

(a) Distribution of velocity  
(b) Distribution of vorticity

**Fig. 1** Distributions of (a) velocity and (b) vorticity at 150 mm downstream from the edge of nozzle.

A47. Peeling Off of Coating Film at Constriction Model Surface by Cavitation

Daisuke Kobayashi¹, Hisanobu Kawashima², Toshio Watanabe³, Takuya Sato³ and Tsuneaki Ishima²

¹Graduate School of Science and Technology, Gunma University, Japan  
²Division of Mechanical Science Technology, Gunma University, Japan  
³Marine engineering, SUZUKI MOTOR CORPORATION, Japan  
E-mail: t201b036@gunma-u.ac.jp

The protecting of surface by painting is important for keeping appearance and its performance. For example, a ship propeller surface is painted in order to protect from a rust, corrosion and so on. Sometimes ship propellers are damaged by cavitation erosion. A cavitation
produces a strong impulse force at the collapse motion of cavitation bubble. When the impulse force acts on the ship propeller, it causes a serious damage. It might cause the peeling of painted coating on the propeller surface. The purpose of this experimental study is to investigate the peeling of the coating paint on the model surface in cavitating flow.

The experiments are carried out in a circular water tunnel for cavitation. The circular water tunnel consists of a water tank, inline pomp, flow channel with transparent acrylic visualization part and magnetic flowmeter. A painted shrinkage model with 26mm in width covered by coating with an anodizing film is inserted in acrylic visualization part. The installed shrinkage model is painted with a luminescent paint to evaluate the peeling area of film coating by cavitation. The peeling area of coating film is analyzed by comparing model pictures before and after the experiment. Figure 1 shows the evaluated peeling area under the different flow velocities. The experiment is performed three times in same flow condition. The peeling area increased when the mean flow velocity is increasing.

The peeling area of coating film in cavitating flow is evaluated with a circular water tunnel. The peeling area increased with an increase in the mean flow velocity becomes large.

![Fig. 1 Peeling area of coating film](image-url)