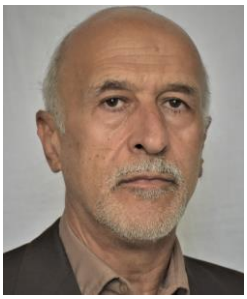
The 1st Korea-Iran
Joint Workshop on Thermo-Fluids Engineering

Pusan National University, Busan 46241, Korea
26th March, 2021

Organized by School of Mechanical Engineering, Pusan National University
Supported by National Research Foundation of Korea,
BK FOUR and Eco-friendly Smart Ship Parts Technology Innovation Center

Welcome



March 26, 2021

Dear Participants,

As co-chairs of the 1st Korea-Iran Joint Workshop on Thermo-Fluids Engineering, we would like to warmly welcome you all to Pusan National University. This workshop was planned as an activity for the Korea-Iran academic exchange program being accepted by NRF, Korea in 2020. Against all odds caused by COVID-19 situation, we are confident that this workshop will grant each of you one day full of exciting and productive events.

Both Iranian and Korean scientists are interesting in the subject of thermal fluid engineering due to its broad application backgrounds in various fields of aerospace and mechanical engineering. Thus, Iranian and Korean expert group attending the "The 1st Korea-Iran Joint Workshop on Thermo-fluids Engineering" will be formed to share the latest research results with each other. The workshop will particularly focus on the cutting-edge topics in the fields of turbulence, multiphase flow, heat transfer, flow control, and advanced experimental techniques and data processing methods. For a cultural exchange, traditional music of Korea and Iran will be performed.

The first joint workshop was organized by Pusan National University (PNU) and supported by National Research Foundation of Korea. This workshop is also supported by BK FOUR program in School of Mechanical Engineering, Pusan National University and the regional leading research center (RLRC) entitled Eco-friendly Smart Ship Parts Technology Innovation Center. We are grateful for the supports.

With our utmost pleasure, we now officially open the 1st^{h} Korea-Iran Joint Workshop on Thermo-Fluids Engineering. Many thanks, and please enjoy your workshop here in PNU campus.

Prof. Juhun Song and Prof. Javad Abolfazli Esfahani

Co-chair of 1st Korea-Iran Joint Workshop

Professor, School of Mechanical Engineering, Pusan National University, Busan 46241, Korea

Professor, Department of Mechanical Engineering, Ferdowsi University of Mashhad, Mashhad 91775-1111, Iran

The 1st Korea-Iran Joint Workshop on Thermo-fluids Engineering

Workshop Program

Friday 26 March, 2021 (Room 207, ME building)

Time	Title	Speaker	University
09:00 – 09:10	Chairman's Welcome Speech	Prof. Juhun Song	Pusan National University, Korea
Session 1 (Chair: Prof. J Song, PNU)			
09:10 – 09:30	CFD and Machine Learning Based Heat Transfer Enhancement by Insert	Prof. Javad Abolfazli Esfahani	Ferdowsi University of Mashhad, Iran
09:30 – 09:50	Influence of Slip Velocity in a Two-phase Bubble Plume	Prof. Kyung Chun Kim	Pusan National University, Korea
09:50 – 10:10	Development of a full 3D inverse design method for curved ducts	Prof. Mahdi Nili-Ahmadabadi	Isfahan University of Technology, Iran
10:10– 10:25	**Coffee Break**		
Session 2 (Chair: Prof. JA Esfahani, FUM)			
10:25 – 10:45	Effect of Particle Fragmentation on Combustion and Emissions in PCI System	Prof. Chung-Hwan Jeon	Pusan National University, Korea
10:45 – 11:05	Study on the liquid sheet of two colliding jets in different asymmetric conditions	Prof. Azadh Kebriaee	Sharif University of Technology, Iran
11:05 – 11:25	Numerical analysis of radiation characteristics of burning coal between two planar walls	Prof. Juhun Song	Pusan National University, Korea
11:25 – 11:30	**Photo Time**		
11:30 – 13:30	**Lunch**		
Session 3 (Chair: Prof. KC Kim, PNU)			
13:30 – 13:50	Vibration-based Energy Harvesting Using Electromagnetic and Piezoelectric Transducers	Prof. Aref Afsharfard	Ferdowsi University of Mashhad, Iran
13:50 – 14:10	Impact behaviors of an impinging drop on various surfaces	Prof. Eunseop Yeom	Pusan National University, Korea
14:10 – 14:30	Breaking Bow Waves Simulated by a 2D+T Technique	Prof. Mohammad Reza Tavakoli	Isfahan University of Technology, Iran
14:30 – 14:50	Attached structures in wall-bounded turbulent flows	Prof. Jinyul Hwang	Pusan National University, Korea
14:50 – 15:10	**Coffee Break**		
Musical Performance			
15:10 – 15:40	Iranian Traditional Music and Korean Traditional Music	Ms. Min Kyung Jeon, Ms. Soohyun Lee, Mr. Mohammad Hossein Kashefi, Mr. Sayed Mehrdad Bathaei	Pusan National University, Korea
15:40 – 15:50	Closing Remark	Prof. JA Esfahani Prof. CH Jeon	FUM, Iran PNU, Korea

CFD and Machine Learning Based Heat Transfer Enhancement by Insert

Javad Abolfazli Esfahani

Department of Mechanical Engineering, Ferdowsi University of Mashhad, Mashhad 91775-1111, Iran
School of Mechanical Engineering, Pusan National University, Busan 46241, Korea

There is a much greater catastrophic environmental crisis than COVID impending: the climate change. Energy and environmental crises are tightly linked because it is almost impractical to generate, carry, or consume energy without substantial environmental impact. The environmental challenges precisely connected to energy production and consumption consist of air pollution, thermal pollution, climate change, water pollution, and solid waste disposal. The emission of air pollutants from fossil fuel combustion is the key source of metropolitan air pollution. Burning fossil fuels is the major supplier to the emission of greenhouse gases. To tackle this problem, there are three ways: 1. replacing new resources, 2. enhanced the efficiency of equipment, 3. management of consumption. This work presents the effect of inserts on enhancement of heat transfer in heat exchanger and boiler. Heat transfer augmentation by integrating twisted tapes is because of:

• Generating swirl flow inside tubes, leading to improve the circulation of the heat exchange fluid between the wall and the center of the tube;
• Increasing the fluid flow path through the pipe, which improves the heat transfer rate;
• Reducing the thermal boundary layer near the wall of the tube, which the smaller thermal boundary layer, the more heat transfer rate;
• Proposing the fin effect in the cross-section perpendicular through the tube

Several inserts are analysed and presented, and typical results are shown as Fig. 1. The effect of design parameters on Nusselt number and friction factor of the fluid flow through tubes fitted with insert and thermal performance are discussed. A numerical study is necessary for better understanding the physical impacts of different geometrical parameters on the turbulent flow characteristics in the presence of the inserts. Also, the impact of the geometrical parameters requires to be additional examined to determine in which circumstances the highest thermal performance factor could be obtained. Accordingly, the main objectives in the present investigation are to cover this topic and utilize correlations to predict the thermal performance and heat transfer augmentation of the system as functions of the model parameters. For this purpose, various inserts with variable geometrical constraints and perforated index are fitted at the center of a heat exchanger tube.

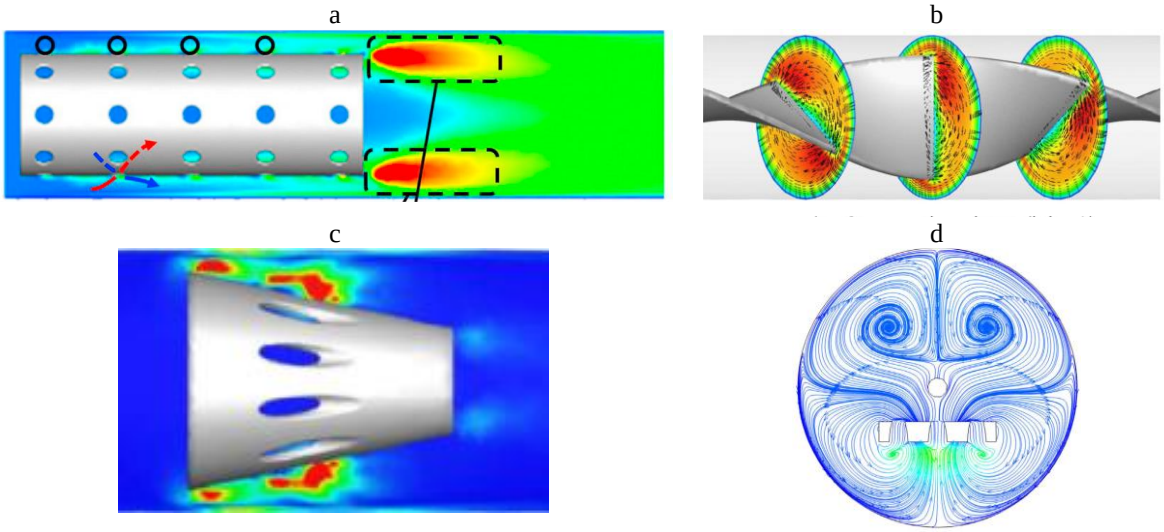


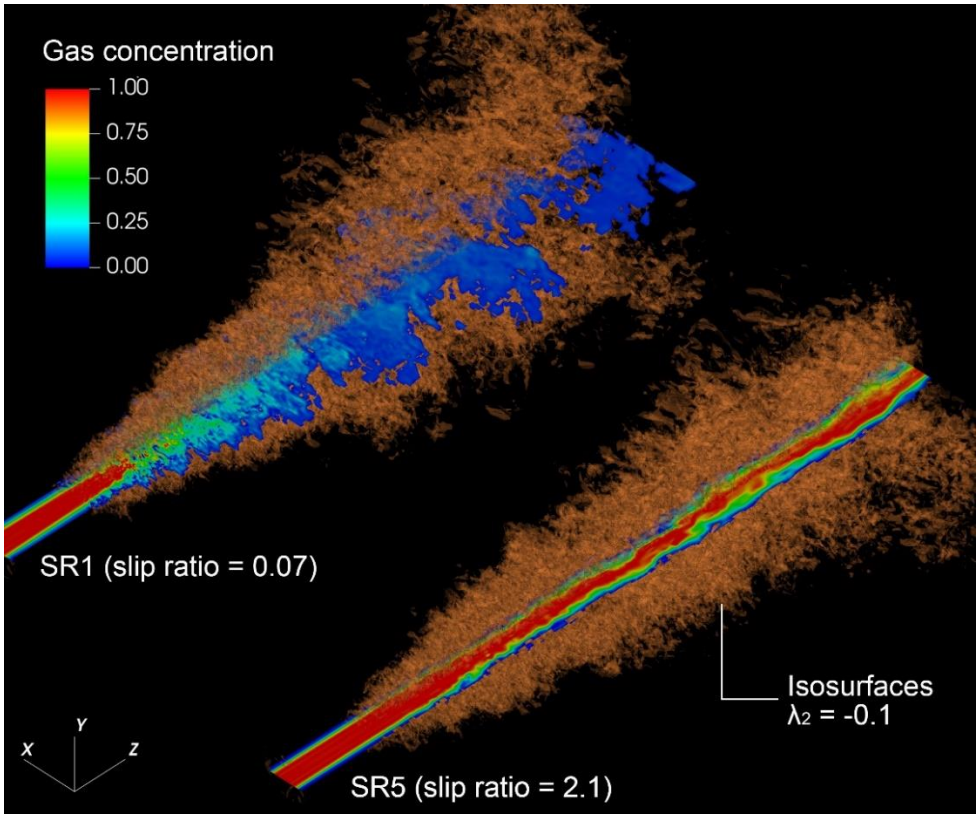
Fig. 1 flow characteristic a) hollow cylinder b) twisted tape c) conical ring d) louvered strip

Influence of Slip Velocity in a Two-phase Bubble Plume

Kyung Chun Kim

School of Mechanical Engineering, Pusan National University, Busan 46241, Korea

The effect of the slip velocity in bubble plumes is studied with various bubble slip ratios (0.07 to 2.1 times the inlet velocity). The governing equations, which are the conservation of mass, momentum and volume fraction, are solved by direct numerical simulation. A set of ordinary differential equations was derived by using a conventional one-dimensional integral framework on plumes and by expressing the slip velocity using an exponential function. The one-dimensional analysis of bubble plumes successfully predicted the plume velocity radius, centreline velocity, and the gas spread rate downstream of the plume. Second and third order statistics were also analysed to better understand the turbulent characteristics of the plume. A high slip ratio results in a rigid, narrower plume-core region, where the turbulent kinetic energy is conserved along the centreline but does not diffuse towards the ambient region. The narrow, circular region around the plume core at high slip ratios decreased the turbulent kinetic energy. In the rigid plume core, turbulent diffusion of the gas phase is suppressed and has low correlations with the velocity fluctuations. Turbulence characteristics such as turbulence stress were compared with single-phase plume results from existing literature. The magnitude of the turbulence characteristics at the lowest slip ratio is comparable with what is found in literature, but there is a rapid transition from slip ratios of 0.14 to 0.7. Furthermore, the turbulent kinetic energy budget was analysed for each case. The production term had the most contribution, and its magnitude was almost five times the buoyancy production downstream. High-slip ratio cases showed a positive peak of pressure strain and turbulent diffusion along the centreline.



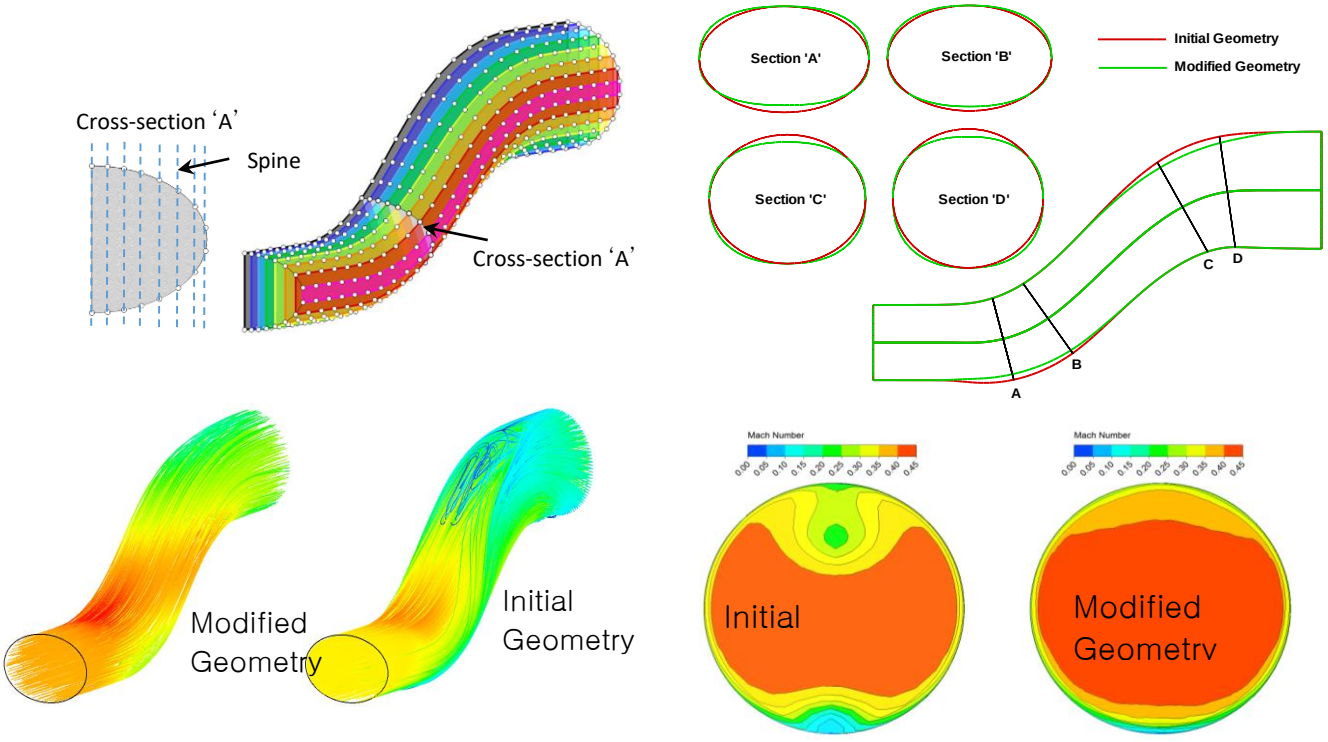
Direct Numerical Simulation of turbulent bubble plumes using a Eulerian-Eulerian approach. Gas concentration fields and isosurfaces of λ_2 vortices are shown for two different slip ratio, 0.07 and 2.1

Development of a full 3D inverse design method for curved ducts

Mahdi Nili-Ahmadabadi

Department of Mechanical Engineering, Isfahan University of Technology, Isfahan, Iran

In this study, a new inverse design method is proposed for the full 3-D inverse design of S-ducts using the curvature-based dimensionless pressure distribution as a target function. The wall pressure distribution in a 3-D curved duct is a function of the center-line curvature and the cross-sectional profile and area. A dimensionless pressure parameter was obtained as a function of the duct curvature and height of the cross-sections based on the normal pressure gradient equation. The dimensionless pressure parameter was used to eliminate the effect of the cross-sectional area on the wall pressure distribution. Full 3-D inverse design of an S-shaped duct was carried out by substituting the 3-D duct with a large number of 2-D planar ducts. The ball-spine inverse design method with vertical spins was coupled with the dimensionless pressure parameter as a target function for the design of the planar ducts. The inverse design process was performed in two steps. First, the height of each cross-section was considered constant, and only the duct centerline was allowed to be deformed by applying the difference between the dimensionless pressure on the upper and lower lines of symmetry plane. Then, a constant curvature was considered for each centerline in the equation, and the difference between the current and the target dimensionless pressure was applied to each upper and lower line of the planar sections to correct the heights of the 2-D planar sections, separately. The method was validated by choosing a straight duct as an initial guess, which converges to the target S-shaped duct. The results showed that the method is an efficient physical-based residual-correction method with low computational cost and good convergence rate. The 3-D wall pressure distribution of a high-deflected 3-D S-shaped diffuser was modified to eliminate the separation, secondary flow, and outlet distortion. Finally, the geometry corresponding to the modified pressure was obtained by the proposed 3-D inverse design method, which revealed a higher pressure recovery, lower total pressure loss, and lower outlet flow distortion and swirl angle.

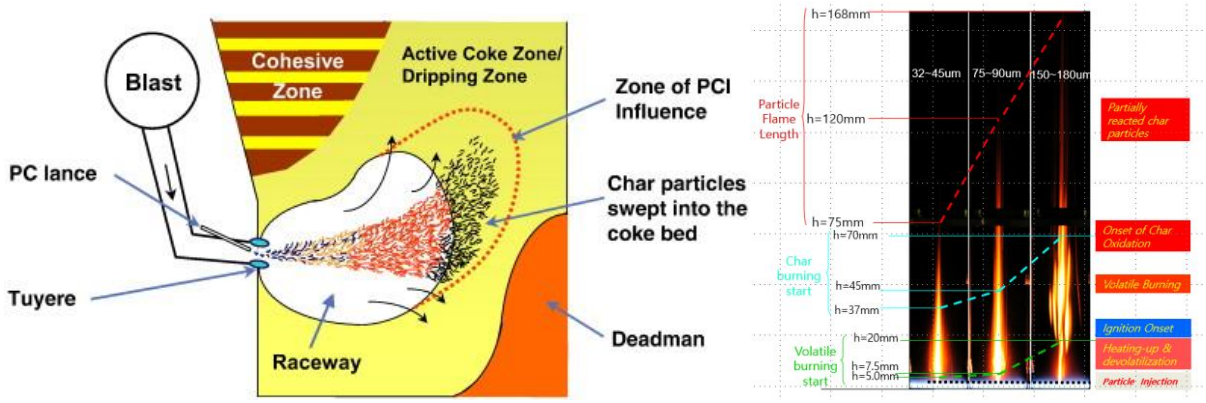


Effect of Particle Fragmentation Behavior on Combustion and Emissions in Pulverized Coal Injection System

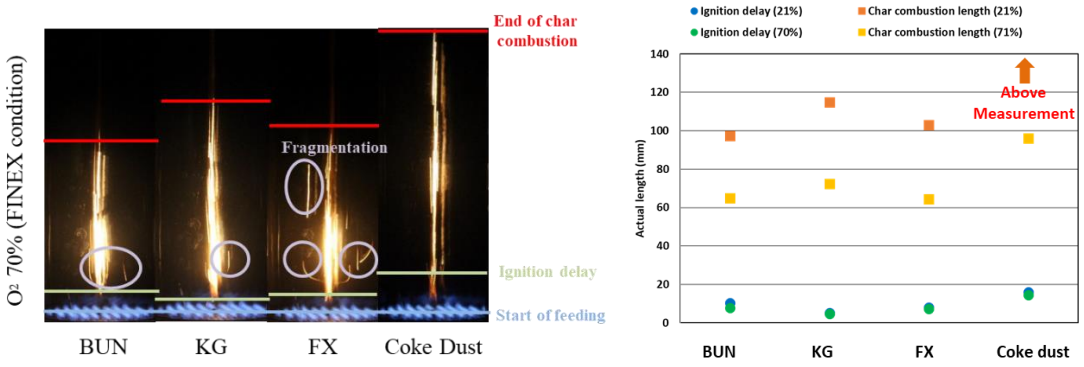
Chung-Hwan Jeon

School of Mechanical Engineering, Pusan National University, Busan 46241, Korea

This study aims to find out the fragmentation effects of the high volatile coals that used in the Pulverized Coal Injection (PCI) system, which is one of the highly efficient iron making process. The experiment has been conducted with the Laminar Flow Reactor(LFR) equipped at Pusan Clean Energy Research Institute. The LFR could visualization the coal during the combustion, which also could described the fire raceway of coal in PCI system. The major characteristics of coal combustion are the ignition delay, volatile matter combustion, char combustion, and fragmentation effect of coals. They can be measured in the real terms and also can be calculated to the combustion velocities that is critical to identify the coal combustion behavior and mechanism. In order to identify the effect of fragmentation of coals, the Particle Size Distribution (PSD) experiment has been conducted and compared coal size before experiment and after fragmentation. In overall, the Fragmentation results were checked qualitatively using LFR, the Fragmentation effect was quantitatively analyzed through PSD after receiving the detected samples. And the gas Analyzer has been used for detecting the gas emission after the combustion. After estimate the result of the experiment, the simulation of the race way will be future work for estimating the Fragmentation effects of the coals. The simulation of the raceway will be conducted in the several models such as Eulerian-Eulerian; two-fluid model and Eulerian-Lagrangian;(DEM) model and etc.



The combustion characteristic of LFR system for PCI in Iron making process



Visualization on the fragmentation effect of solid fuel particles using LFR

Study on the liquid sheet of two colliding jets in different asymmetric conditions

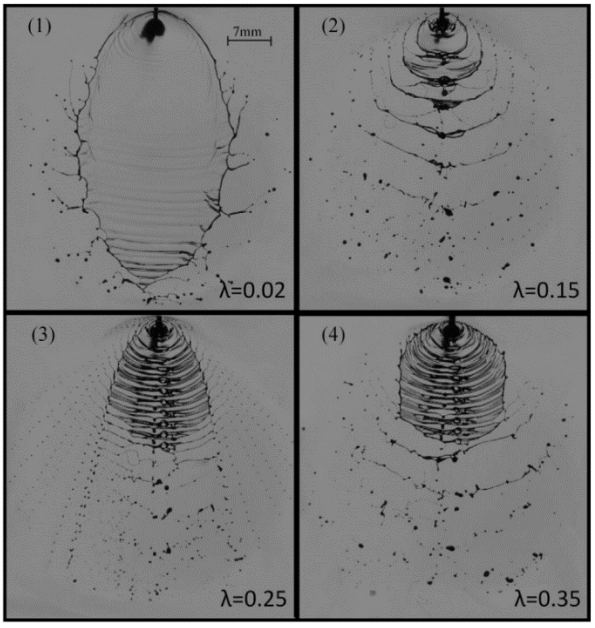
Azadeh Kebriaee

Aerospace Engineering Department, Sharif University of Technology, Tehran, Iran

Collision of two or more jets is a method to spray and atomize liquids in different industries. When two jets collide at low liquid jet velocities, a leaf-shaped liquid sheet (normal to the plane of the two jets), bounded by a thicker rim, is formed. When the velocity of jets increases, the liquid sheet breaks from the downside, where an unstable liquid sheet with disintegrated ligaments and droplets is created. The characteristics of the liquid sheet, liquid rim, ligaments, and the droplets depend on different factors such as the geometry of the nozzle, the regime and colliding angle of the liquid jets, properties of the fluid.

The patterns and geometrical properties of the liquid sheet formed by the two colliding jets were investigated under some anomaly conditions including the skewness in the collision of two jets and the difference in the jets velocity and diameters. Our study was bounded to low Reynolds number to capture the pattern of changes in the liquid sheet shape for all laminar sheet regimes, known as triple-chain, double-chain, closed-rim, and open-rim.

The general effect of the skewness involved shortening and widening the liquid sheet. The liquid rim also became thicker by increasing the skewness for all regimes. For the liquid sheet with different jets velocities, in addition to the rotation of the liquid sheet, different unstable liquid sheet patterns were observed. It seems that the source of this kind of instability could be attributed to the excess flow rate of one jet, disturbing the velocity distribution of the liquid sheet. It was also shown that two jets with the different diameter but with the same jets momentum can form both stable and unstable liquid sheet. The maximum length and width of the liquid sheet both decrease by falling the liquid sheet to the unstable regime due to the diameter difference.



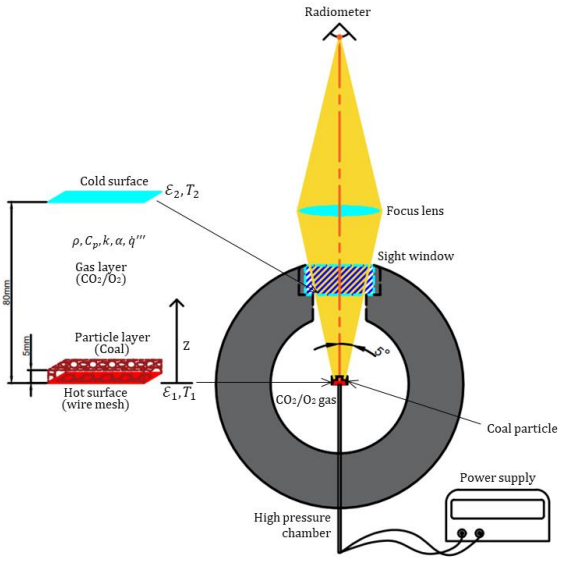
Evolution of the liquid sheet patterns formed due to the difference in the velocity of the two identical liquid jets, for open rim regime, Re = 290, (a) λ=0.02, (b) λ=0.15, (c) λ=0.25, (d) λ=0.35.

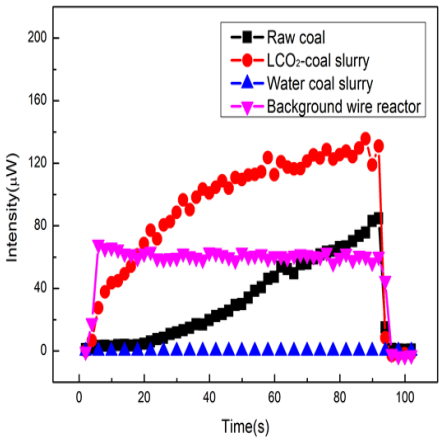
Numerical analysis of radiation characteristics of burning coal between two planar walls

Juhun Song

School of Mechanical Engineering, Pusan National University, Busan 46241, Korea

Numerical study has been performed to predict radiation characteristic of burning coal between two planar walls. One-dimensional unsteady energy balance equation and radiation transfer equation (RTE) were solved simultaneously using discrete ordinate method (DOM). Semi implicit Runge Kutta (SIRK) method was combined with step halving method to save computational time for this case where optical thickness was substantially high. Dimensionless heat flux and temperature distribution over two layers filled with coal and CO_2/O_2 gas were determined. This transient data was compared with experimental data measured from radiometer and two-color pyrometer. The effects of optical thickness and heat generation within the burning coal layers were further discussed in this presentation. Finally, two dimensional effect and spectral effect were briefly mentioned to improve the accuracy of this analysis.



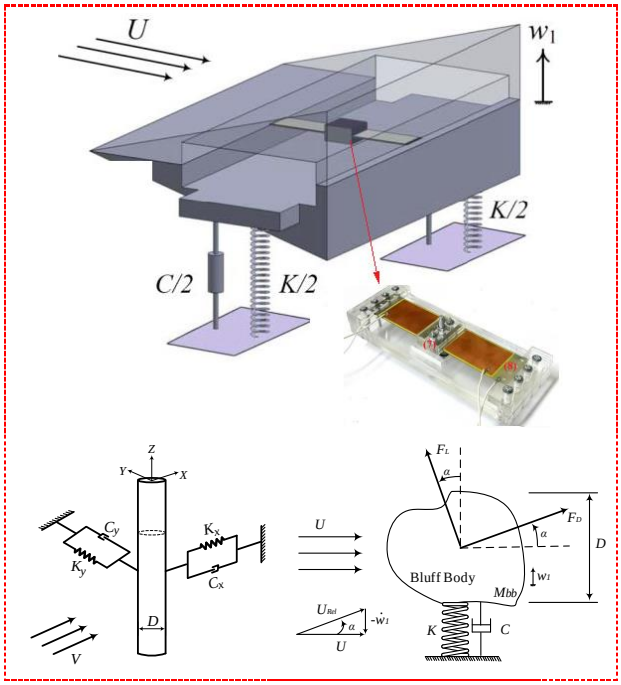


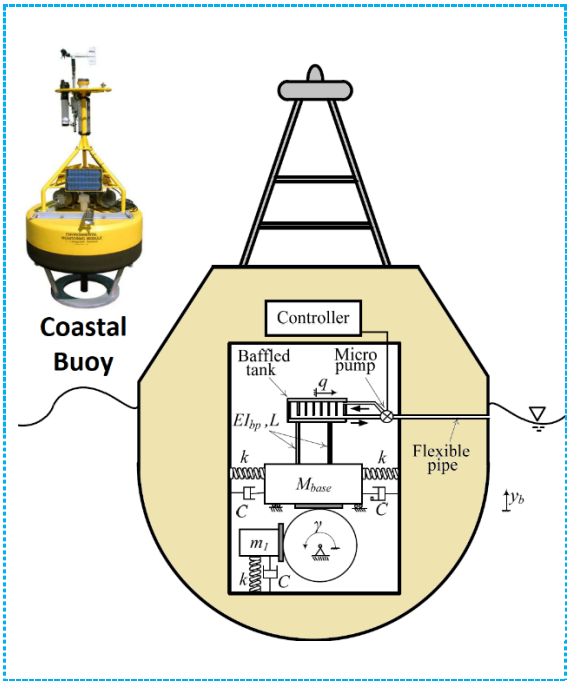
Vibration-based Energy Harvesting Using Electromagnetic and Piezoelectric Transducers

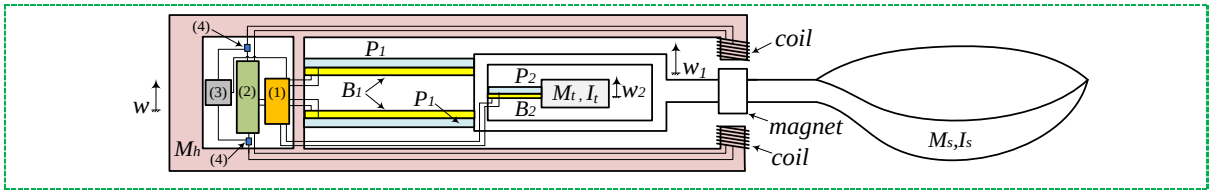
Aref Afsharfard

Mechanical Engineering Department, Ferdowsi University of Mashhad, Mashhad, Iran

Ambient energy like Ocean wave energy and wind energy are huge energy sources, which easily wasted around us. Because of low frequency of the ocean waves, less attention has been paid on vibration-based energy harvesting from this energy source. It should be noted that, well designed vibratory systems can act as a mechanical reliable magnifier for energy harvesting goal. For example, a new design of beam-column piezoelectric-based energy harvesting system can be optimally used as an Ocean Wave Energy Harvester. To design a vibration-based energy harvester, at first, the dynamic characteristic of system should be defined. To do so, the electromechanical equations of motion for the energy harvesting system can accurately be derived using the Hamilton's principle. Then, regarding to the idea of resonance, the vibratory system (mechanical magnifier) will be optimized. In this workshop, at the first step, importance and market of energy harvesting is presented. Then, applications of several vibration-based energy harvesting systems are discussed. For example, in case of offshore buoy it is shown that a passive vibration-based energy harvesting mechanism can provide enough energy for the electrical devices in the buoy. Flow induced vibration-based energy harvesting systems are one of energy harvesters, which should extensively be considered. in this workshop, application of a galloping-based piezoelectric energy harvester is investigated in a realistic condition. Finally, medical and industrial applications of the piezoelectric and electromagnetic devices for energy harvesting and vibration suppression is discussed.







Impact behaviors of an impinging drop on various surfaces

Eunseop Yeom

School of Mechanical Engineering, Pusan National University, Busan 46241, Korea

Drop impingement can be easily observed in numerous industrial applications and nature. A surface patterns can change water repellency and impose directional wettability. For that, surfaces with periodic microscale grooves were used to investigate the impact behaviors on the surfaces. Figure 1 shows the wetting state and the directional behaviors on micro-grooved PDMS surfaces. In case of smooth PDMS surface, the liquid of the impinging drop gently spreads and then recedes. After the receding phase, the contact line is pinned and it is followed by damped oscillations of the top interface. Regardless of We, the bouncing phenomenon is not observed on the smooth surface. However, the droplet on PDMS surface with grooves having widths of 20 μm starts to rebound from the smallest We. Specifically, the contact lines are not pinned in the receding phase and finally bounce off without remnant liquid on the surface. As shown in the bottom inset of Fig. 1, the contact line is pinned in the receding phase, and a part of the drop sticks to the surface when We is higher than 15. As expected, the length of contact line(D) is distinguishable between the parallel and perpendicular directions. The D∥ almost followed the tendency observed from the smooth surface like the case in this study. The D⊥ have shown two different receding rates; the first rate was significantly slower than that of the second. For all the micro-grooved surfaces, the maximum spreading factor measured perpendicular to the groove direction (βm⊥), are smaller than those measured parallel to the groove (βm∥). The difference between them becomes to be clear as We increases. The pinning of the drop to the pillar top and the impalement transition can inhibit the spreading of the drop liquid perpendicular to the groove direction.

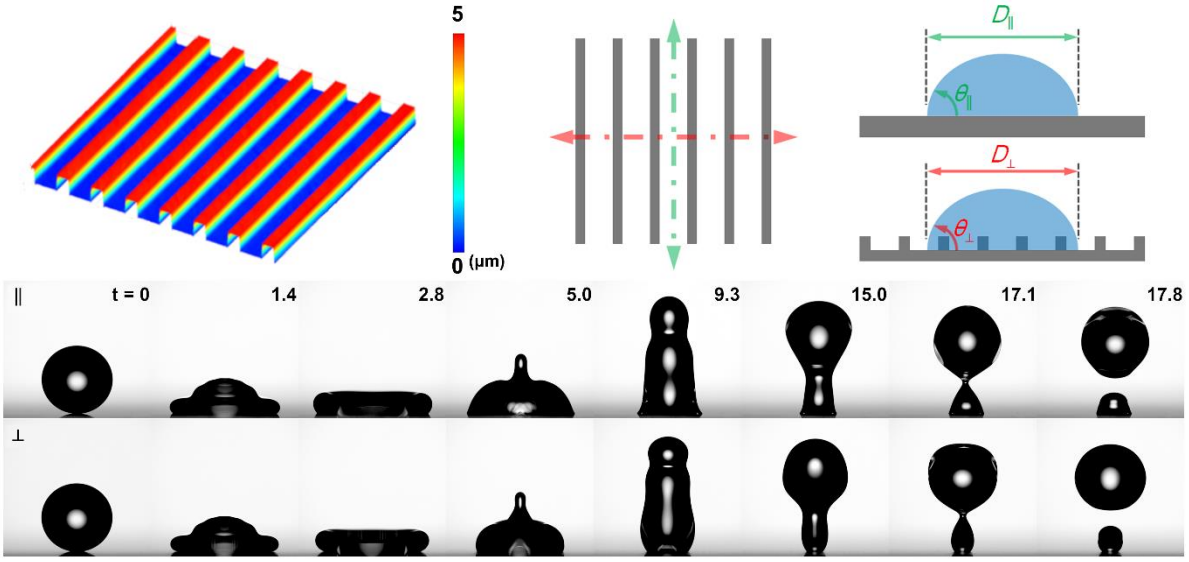


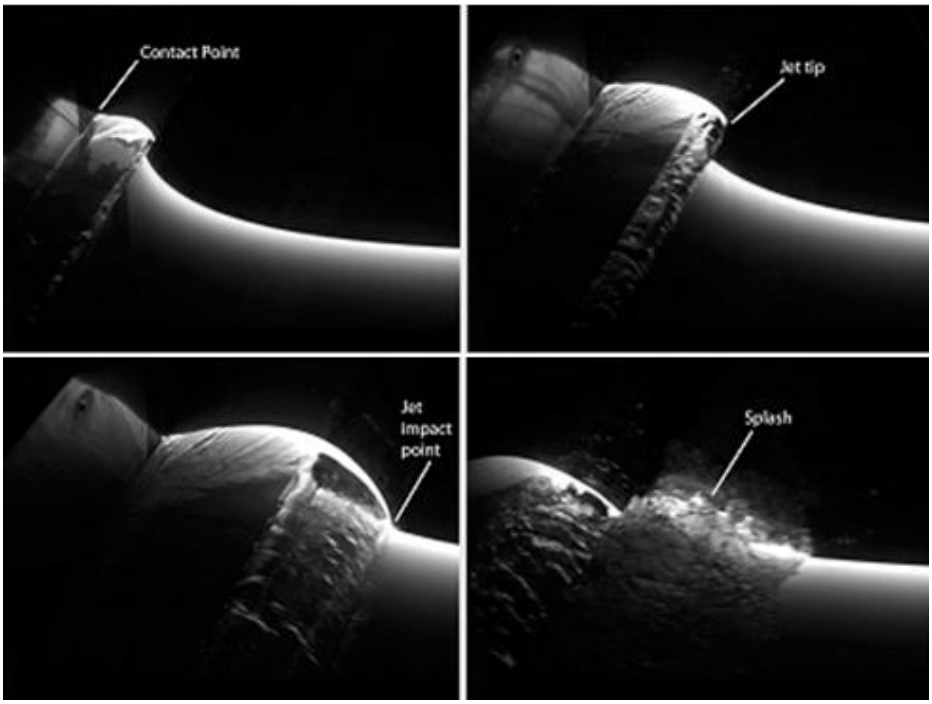
Fig. 1 Three-dimensional schematic image and two orthogonal measurement directions with respect to the groove length direction. Impact sequences of the droplets having the same *We* = 15.2 on the groove with 20 μm.

Breaking Bow Waves Simulated by a 2D+T Technique

Mohammad Reza Tavakoli

Department of Mechanical Engineering, Isfahan University of Technology (IUT), Isfahan 84156, Iran

Experimental studies of breaking bow waves are essential for advancing the understanding of these flows and creating valid models. This experimental research is part of a larger project whose broad goal is to improve our understanding of the dynamics of breaking bow waves including the time history of the water surface shape and the entrainment of air bubbles into the flow. The bow waves studied in this project are generated with a technique known as 2D+T. The time history of the water surface shape was measured with a cinematic laser-induced fluorescence technique (LIF). The waves produced ranged from small-amplitude non-breaking waves to plunging breakers at the high Froude numbers. These waves are strongly forced and at the higher Froude numbers begin breaking before leaving the wave board. The time histories of various geometric characteristics of the water surface shape including the hull contact line, the wave crest, the plunging jet, and the splash zone were measured. The primary mechanisms for air entrainment are the impact of the plunging wave jet and individual droplets in the splash region on the free surface and the air bubbles are entrained in spatially periodic bubble clouds. In this project, a shadowgraph technique is developed for the measurement of bubble size distributions, bubble motions, and the void fraction as a function of the equivalent forward speed of the model. The time history of the water surface shape, the air entrainment in bow waves simulated by a 2D+T technique, and the methods used to analyze these phenomena should provide a valuable set of data and analyses for the study of breaking bow wave mechanics.

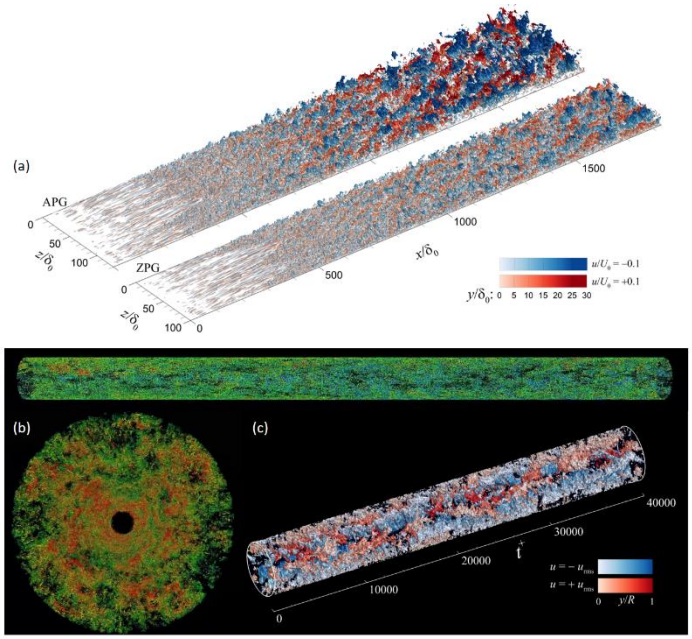


Attached structures in wall-bounded turbulent flows

Jinyul Hwang

School of Mechanical Engineering, Pusan National University, Busan 46241, Korea

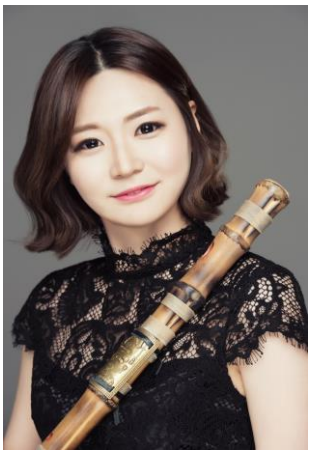
Wall turbulence is a ubiquitous phenomenon in nature and engineering applications, yet predicting such turbulence is difficult due to its complexity. High-Reynolds-number turbulence arises in most practical flows, and is particularly complicated because of its wide range of scales. Although the attached-eddy hypothesis postulated by Townsend can be used to predict turbulence intensities and serves as a unified theory for the asymptotic behaviours of turbulence, the presence of coherent structures that contribute to the logarithmic behaviours has not been observed in instantaneous flow fields. Here, we demonstrate the logarithmic region of the turbulent intensity by identifying wall-attached structures of the velocity fluctuations (u_i) through the direct numerical simulation of a moderate-Reynolds-number boundary layer ($Re_\tau \approx 1000$). The wall-attached structures are self-similar with respect to their heights (l_y), and in particular the population density of the streamwise component (u) scales inversely with l_y, reminiscent of the hierarchy of attached eddies. The turbulence intensities contained within the wall-parallel components (u and w) exhibit the logarithmic behaviour. The tall attached structures ($l_y^+ > 100$) of u are composed of multiple uniform momentum zones (UMZs) with long streamwise extents, whereas those of the cross-stream components (v and w) are relatively short with a comparable width, suggesting the presence of tall vortical structures associated with multiple UMZs. The magnitude of the near-wall peak observed in the streamwise turbulent intensity increases with increasing l_y, reflecting the nested hierarchies of the attached u structures. These findings suggest that the identified structures are prime candidates for Townsend's attached-eddy hypothesis and that they can serve as cornerstones for understanding the multiscale phenomena of high-Reynolds-number boundary layers.



(a) 3D isosurfaces of negative and positive streamwise velocity fluctuations in adverse-pressure gradient (APG) and zero-pressure-gradient (ZPG) turbulent boundary layers (Hwang & Sung 2017 *J. Fluid Mech.*; Hwang & Sung 2018 *J. Fluid Mech.*; Yoon *et al*. 2020 *J. Fluid Mech.*; Hwang *et al*. 2020 *J. Fluid Mech.*). (*b*) 3D isosurfaces of swirling strength in turbulent pipe flow at $Re_\tau = 3008$ (Ahn *et al*. 2015 *Phys. Fluids*). (*c*) Time evolution of negative and positive streamwise velocity fluctuations in turbulent minimal pipe flow at $Re_\tau = 927$ (Han *et al*. 2019 *Phys. Fluids*)

Introduction to Musical Performance

Korean Traditional Music



Gayagum, **Ms. Min Kyung Jeon** (전민경)

Lecturer, Department of Korean Music

Pusan National University, Korea

Daegum, **Ms. Soohyun Lee** (이수현)

Graduate student, Department of Korean Music

Pusan National University, Korea

1. **Beautiful Memory (아름다운 추억):** Composed by **Sang Goo Kang (강상구 곡)**

이 세상 모든 사람들은 자기만의 아름다운 추억을 만들어가며 살아간다. 기억 속에 남아 있는 우리들의 추억은 언제까지나 우리들의 마음속에 남아 있다. 이 곡을 통해 잊혀지고 있는 우리들의 아름다운 추억을 되새겨보자.

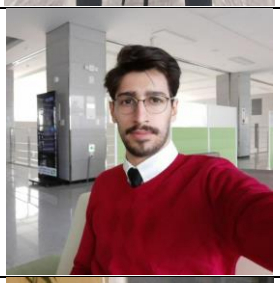
All people in this world live by making their own beautiful memories. Our memories that remain in our life remain in our hearts forever. Let's recall our beautiful memories that are being forgotten through this song.

2. Beetles Medley 비틀즈 메들리(Let it be, Hey Jude, Obladi Oblada)

한국인이 좋아하는 100 대 팝송 중 오랫동안 굳건히 자리를 지키고 있는 Let it be, Hey Jude, Obladi Oblada 의 주인공, 영국이 낳은 전설적인 팝그룹 비틀즈의 대표곡 중 몇 곡을 선정하여 국악으로 편곡하였다.

Among the top 100 popular songs of Koreans, the protagonists of **Let It Be**, **Hey Jude**, **Obladi Oblada**, which have been firmly standing for a long time. Some of the representative songs of the legendary pop-group **The Beatles**, produced by England, were selected and arranged as Korean traditional music.

Iranian Traditional Music

Members of Iranian musical group		
Mr. Mohammad Hossein Kashefi Graduate student School of Mechanical Engineering Pusan National University	Daf player	
Mr. Mehrdad Bathaei Graduate student School of Mechanical Engineering Pusan National University	Violin player	
Mrs. Raha Ariyan English teacher	Vocalist (Invited)	

Traditional Persian Music includes 7 systems (Mode or Dastgah). This classification is technically based on the sound pitch and keynote and emotionally based on the feeling which the music creates in the audience. The names of these Systems are: Shur, Mahur, Rast Panjgah, Segah, Chargah, Nava and Homayun.

The songs to be performed are:

1- Jane Maryam
On Mahoor System
(The glory of this system reminds of good memories and motivates to better future.)

2- Se-Godar
On Homayoon System (Avaz: Isfahan)
(It creates deeply mournful feelings and passionate feeling about meeting the beloved at audience)