The 1st KIM-CSM Symposium : Lightweight materials technol efficient transportation system

위원장 : 권용남(재료연구소)

Room 103, 10월 25일

KC1-1 | 09:45 **Opening address**

Chair : Hyoung-Wook Kim (KIMS),
Wenzheng Zhang (Tsinghua University)

KC1-2 | 10:00

Facets of Precipitates in Light Alloys

Wenzheng Zhang[1]

[1]Tsinghua University.

KC1-3 | 10:30

Development of A6061 Front Knuckle by Tailored Additive Casting Process

Hwi-Jun Kim[1], Chul Lee[1],Sung-Uk Hong[1]

[1]KITECH.

KC1-4 | 11:00

Study on Grain Refinement of Casting Aluminum Alloy for Automobile

Zhang Zhendong[1] Liu Chunhai[1] Lu Hongzhou[2] Wang Wei[1]

[1]CITIC Dicastal. [2]CITIC Metal

KC1-5 | 11:30

Fabrication of High Strength Aluminum Alloy Sheets by Twin Roll Casting and Rolling Process

Hyoung-Wook Kim[1], Yun-Soo Lee[1], Min-Seok Kim[1], Kwangjun Euh[1], Cha-Yong Lim[1]

[1]KIMS.

Chair: Young Min Kim (KIMS),
Yongbing Li (SHANGHAI JIAO TONG UNIVERSITY)

KC2-1 | 13:30

Recent Industrial Application and Research Progress of Mg Alloys In CHINA BAOWU

S.W. Xu[1], W.N. Tang[1], Y. Xie[1]

[1]China Baowu Steel Group

KC2-2 | 14:00

Recent Progress in High Performance Non-flammable Magnesium Alloys

Young Min Kim[1], Joung Sik Suh[1], Bong Sun You[1]

[1]KIMS.

KC2-3 | 14:30

Effect of Process Parameters on Joint Formation in Friction Self-Piercing Riveting (F-SPR) Aluminum Alloy and Magnesium Alloy

Yongbing Li[1]

[1]SHANGHAI JIAO TONG UNIVERSITY.

KC2-4 | 15:00

Heterogeneous Deformation and Twinning Behavior in Mg Alloys under the mini-V-bending and Erichsen Tests

Shi-Hoon Choi[1], Min-Seong Kim[1], Seong-Eum Lee[1], Jaiveer Singh[1]

[1]Sunchon National University.

Chair : Jea Keun Hong (KIMS),
Gaofeng Quan (Southwest Jiaotong University)

KC3-1 | 15:30

Research on Ti Alloys and Their Applications in Transportation in China

Yong-Qing Zhao[1], Qian Li[1]

[1]Northwest Institute for Nonferrous Metal Research.

KC3-2 | 16:00

Strain rate sensitivity of titanium and its alloys

Tea-Sung (Terry) Jun[1]

[1]Incheon National University.

KC3-3 | 16:30

Tentative Research on Ti alloy Application in Bogie Component of Rolling Stocks

Gaofeng Quan[1], Zhengzhi Luo[1], Yangyang Guo[1], Houhong Pan[1]

[1]Southwest Jiaotong University.

KC3-4 | 17:00

Twinning-induced Texture Control of Pure Titanium

Jong Woo Won, Jea Keun Hong[1], Chong Soo Lee[2]

[1]KIMS. [2]POSTECH.

KC3-5 | 17:30 **Discussion**

철강III

위원장 : 최주(POSCO)

총무간사 : 최종교(POSCO)

실무위원 : 박주현(한양대학교), 황병철(서울과학기술대학교)

Room 104, 10월 25일

좌장 : 강영조 (동아대학교)

철강9-1 | 09:00

Effect of SiC Formation on the Wettability of Graphite by Molten Slag

Joonseok Oh[1], Joonho Lee[1]

[1]Korea university.

철강9-2 | 09:15

Dissolution Rate of Alumina into Molten Slags Containing Fe_tO and its Kinetic Modeling

Young-Joon Park[1], Yong-Min Cho[1], Woo-Yeol Cha[2], Youn-Bae Kang[1]

[1]Graduate Institute of Ferrous Technology. [2]POSCO.

철강9-3 | 09:30

The Structure of $CaO-Al_2O_3$ Slag at Different $CaO\ /Al_2O_3$ Ratio by Raman and FTIR Spectroscopy

Ramaraghavulu Rajavarm[1], Donghwi Park[1], Joonho Lee[1]

[1]Korea University.

The 1st KIM-CSM Symposium: Lightweight materials technology for efficient transportation system

Room 103, 10월 25일

[KC1-1 | 09:45] Opening address

[KC1-2 | 10:00]

Facets of Precipitates in Light Alloys: Wenzheng Zhang; *Tsinghua University*

Morphologies of precipitates in light alloys often exhibit fascinating patterns, characterized with facets of reproducible crystallographic orientations. Unlike the faceted surfaces of nature crystals, many of well-defined facets may not be parallel to any low index plane of either or both precipitate and matrix phases, especially those in Ti and Mg alloys. While the links of these facets with singularity of interfacial energy in 5D boundary geometrical phase space is not often clear for rationalizing the facets, the links can usually be elucidated with singularity of the interfacial structures in the dominant facets or the habit planes. A common feature of singular structures is periodicity and singularity of the interfacial structures. Such a singular interface can be identified with its orientation being normal to at least one Dg vector, a vector connecting diffraction spots from different the precipitate and matrix phases. The quantitative connection between singular interfacial structures and measurable vectors in diffraction patterns will be explained based on the O-lattice theory, with a free software available for a detailed calculation. A number of examples of faceted precipitates in different light alloys will be provided.

[KC1-3 | 10:30]

Development of A6061 Front Knuckle by Tailored Additive Casting Process: Hwi-Jun Kim, Chul Lee, Sung-Uk Hong; *KITECH*

Since shrinkage is unavoidable for all metal casts due to density difference between solid state and liquid state, it is required to optimize casting design such as riser, runner, and gate for sound cast during conventional static casting. To minimize energy loss and resources due to casting design and shrinkage, a new casting method (called “tailored additive casting” hereafter) has been suggested, by which the interface between solid and liquid can be progressively moved to the uppermost section through keeping a good balance between solidification rate and melt pouring rate. In this study, we fabricated A6061 front knuckle cast by tailored additive casting and investigated the variation of microstructure and mechanical properties of A6061 front knuckle cast with varying casting parameters such as pouring cycle, pouring rate, pouring time, interval time and each pouring quantity per each step during tailored additive casting process. Internal defect/porosity and microstructure of A6061 front knuckles were observed by X-ray non-destructive inspection and SEM. Mechanical properties were measured by tensile test and hardness test.

[KC1-4 | 11:00]

Study on Grain Refinement of Casting Aluminum Alloy for Automobile: Zhang Zhendong[1], Liu Chunhai[1], Lu Hongzhou[2], Wang Wei[1]; [1]*CITIC Dicastal.* [2]*CITIC Metal*

Al5TiB is the most commonly used master alloy in aluminum alloys, but in the casting aluminum alloy, the Al5TiB master alloy is easy to cause poisoning and fade, resulting in no obvious grain refinement. So, a new grain refiner is needed in casting aluminum alloy. In this paper a newl AlNbB refiner used for casting aluminum alloy A356 will be studied, and the microstructure and mechanical properties of A356 alloy that is used in automobile were investigated by optical microscope, scanning electron microscope and transmission electron microscope. The results showed that the grain refinement effect of AlNbB master alloy is more obvious than that of Al5TiB master alloy, the grain size of AlNbB master alloy was 50% of that of Al5TiB master alloy which makes the casting defects decrease obviously, the microstructure was more uniform and the mechanical properties were improved.

[KC1-5 | 11:30]

Fabrication of High Strength Aluminum Alloy Sheets by Twin Roll Casting and Rolling process: Hyoung-Wook Kim, Yun-Soo Lee, Min-Seok Kim, Kwangjun Euh, Cha-Yong Lim; *KIMS.*

Light weightening of vehicle has been an important issue to improve energy efficiency and air pollution. Many aluminum parts have been developed to replace steel parts, but its strength is still not enough to satisfy automotive manufacture. [1] In addition, the cost for lightweight structures need to be minimized. Twin roll casting is one of cost effective process due to make an aluminum thin strip directly from the melt [2]. Moreover, high cooling rate during twin roll casing can improve the mechanical properties by introducing fine cast structure in several aluminum alloys. However, a conventional twin roll strip casting process has several problems like a limitation of alloy composition and inhomogeneity in microstructures and chemical compositions through the sheet thickness. Especially, it is more difficult to fabricate high strength aluminum alloys with high contents of alloying elements [3]. Al-Mg alloys have a favorable combination of strength and formability as well weldability, and therefore of interest in automotive body application. Also, minor alloying element addition such as Mn increase strength of Al-Mg base alloys by refining grain size and precipitation of fine Al-Mn particles.[4] Particularly, Al-Zn-Mg-Cu alloy have the highest strength among aluminum alloys and has been used for airplane structural parts, the alloy sheets can be anticipated to present more lightweight vehicle structure. In order to make a high strength Al alloy sheet with reasonable cost for automobile application, several high strength aluminum alloy sheets were fabricated by twin roll casting and rolling process in this study. Newly designed ceramic nozzle system and Cu-Cr cooling rolls were used and optimum process parameters such as roll speed and melt temperature were determined [3-5]. After special warm/cold rolling and annealing treatment to control microstructure, the sheets have high strength and good formability. A possibility of the sheets for the automobile body application was discussed on the basis of the mechanical properties of the fabricated sheets. The optimum process conditions to obtain good surface quality of high strength Al-Mg strips with high content of Mg and Al-Zn-Mg-Cu alloy strip were decided.[3-6] The high cooling rates reduced the center segregation and refined the grains and dendrites. The proper annealing treatment reduced inhomogeneity of the microstructure and improved tensile properties. The Al-Mg cast strip obtained in this work showed good workability during rolling process, so that Al-Mg sheet with a thickness of 1 mm was fabricated successfully by cold rolling without any severe cracks. In annealed Al-5.5wt%Mg sheets, tensile strength and yield strength were about 300 MPa and 150 MPa respectively, and elongation was over 25%. The 7075 strip was successfully fabricated by horizontal twin roll casting, the strip have a good workability during subsequent hot rolling and cold rolling after annealing at 400°C for 1hour. The annealed 7075 sheets showed high strength of 370MPa and large elongation of over 20%. After aging at 180°C for 30 minumtes, tensile strength and yield strength of the 7075 sheets were 480MPa and 350MPa, respectively. The sheets fabricated in this paper have a superior tensile property to a commercial aluminum sheets for automobile body application, so that the developed sheets could be used for automobile lightweight structural parts. Twin roll casting and rolling process with a proper heat treatment might be one of promising way to make high strength aluminum alloy with low cost.

[KC2-1 | 13:30]

Recent Industrial Application and Research Progress of Mg Alloys In CHINA BAOWU: S.W. Xu, W.N. Tang, Y. Xie; *China Baowu Steel Group*

In this study, the recent industrial application of magnesium alloy in China Baowu was firstly introduced. From 2015 to 2017, China Baowu has developed two types of magnesium instrument panel beams for China's domestic cars and five types of magnesium alloy parts for China's high-speed rail cars, which significantly boosts the industrialization of magnesium alloys. The recent research progress of magnesium alloys in China Baowu was then introduced. Several kinds of Mg-Al-Zn-Ca alloys with the diameter up to 160 mm were extruded at the temperature range from 350°C to 420°C under the ram speeds from 0.2 to 1.0 mm s^{-1} into different profiles with various cross sections for the applications in the automobile and high-speed rail cars. The influences of homogenization treatment before hot extrusion, the ram speed and the heating temperature during hot extrusion on the microstructure and mechanical properties of extruded products were systematically investigated by electron backscattering diffraction (EBSD) analysis, transmission electron microscopy (TEM) and tensile tests. Through the optimization of extrusion processes, one kind of extruded rod with the diameter up to 50 mm exhibits a tensile 0.2% proof stress of 320 MPa and an ultimate tensile strength of 400 MPa with a tensile elongation to failure of 8 %. Furthermore, several kinds of extruded sheets with a thickness of 1.5 mm and a width of 120 to 180 mm have been developed, which can be bent at the room temperature to 180 degree over and over again without cracking. It should be stressed that, this remarkable phenomenon hardly was achieved in the industrial products which were manufactured merely by one pass optimized extrusion process. These findings provided a new pathway for designing and developing magnesium alloy products with high formability at room temperature compared to those traditionally difficult to form at room temperature. Up to now, these extruded sheets show a tensile 0.2% proof stress up to 150 MPa and an ultimate tensile strength up to 240 MPa with a large tensile elongation to failure up to 35 %.

[KC2-2 | 14:00]

Recent Progress in High Performance Non-flammable Magnesium Alloys: Young Min Kim, Joung Sik Suh, Bong Sun You; *KIMS*

Keywords: Magnesium alloys, Non-flammability, Corrosion resistance, Extrusion

Magnesium alloys are the lightest metal construction materials, and offer great potential for improving energy efficiency of transportation vehicles. However, practical application is still very limited to this day. The reason is that not only formability at room temperature but also ignition and corrosion resistance are remarkably low. The KIMS' research team reported that the combined addition of Ca and Y is very effective in simultaneously improving the non-flammability and corrosion resistance of Mg alloys by formation of multiple oxidation protective layers on Mg grains. As a result, the ignition temperature is increased to higher than 700 °C and the corrosion behavior is significantly enhanced as compared with the AZ alloy. Moreover, no use of a mixture SF_6 and CO_2 enables environmentally friendly processes and materials when manufacturing Mg alloy. Furthermore, this feature is not limited to a specific alloy composition, but can be optimized in accordance with process and product requirements. This has enabled the FAA flammability test to meet the flammability performance requirements and to be applied to aircraft seats. In this presentation, we introduce the microstructural and mechanical characterization of high-strength non-flammable corrosion-resistant Mg alloy regarding extrusion temperature.

[KC2-3 | 14:30]
Effect of Process Parameters on Joint Formation in Friction Self-Piercing Riveting (F-SPR) Aluminum Alloy and Magnesium Alloy: Yongbing Li; *SHANGHAI JIAO TONG UNIVERSITY*

Driven by the requirements of emission control and vehicle performance improvement, mass saving strategy has been widely adopted in the design and fabrication of vehicle body structures. High specific strength materials, including aluminum alloys and magnesium alloys are gradually applied into vehicle bodies to replace traditional steels in some structures for the purpose of reducing the weight without losing the strength [1]. The design and construction usually follows a strategy of the right material for the right application, which raised the demand of combining multi-materials in one integrated structure. Coupled with these requirements, it is necessary to develop a reliable spot joining technology for Al-Mg dissimilar materials. Friction self-piercing riveting (F-SPR) process has been proved capable of joining aluminum alloys and magnesium alloys, and has several advantages over fusion welding, solid state welding and traditional mechanical joining processes in joining dissimilar as well as low ductility materials. Because of the thermo-mechanical nature of F-SPR process, the formation of the joint is determined by riveting force and softening degree of the materials. However, it is still not clear that how exactly the riveting force and generated frictional heat jointly influence the mechanical interlock formation and inhibit cracks during F-SPR process. To address these issues, in current study, F-SPR process was applied to join 2.2 mm-thick AA6061-T6 aluminum alloy to 2.0 mm-thick AZ31B magnesium alloy. The correlation of riveting force, torque responses as well as energy input under a wide range of process parameter combinations with joint quality were investigated systematically. It was found that a relatively greater final peak force and higher energy input were favorable to produce sound joints. Based on that, a two-stage F-SPR process was proposed to better control the energy input and riveting force. It was found that the joints produced by the two-stage F-SPR process exhibited significantly improved lap-shear strength, i.e., 70% higher compared to traditional SPR joints and 30% higher compared to the joints of one-stage F-SPR process.

[KC2-4 | 15:00]
Heterogeneous Deformation and Twinning Behavior in Mg Alloys under the mini-V-bending and Erichsen Tests: Shi-Hoon Choi[1], Min-Seong Kim[1], Seong-Eum Lee[1], Jaiveer Singh[1]; [1]*Sunchon National University*

The heterogeneous deformation and twinning behaviors in the thickness direction of magnesium (Mg) alloy sheets were investigated via mini-V-bending and conventional Erichsen testing at room temperature (RT). Formability of Mg alloys was discussed in terms of punch stroke (PS) and Erichsen index (IE) during mini-V-bending and Erichsen tests, respectively. Microstructure evolution in E-form and AZ31 Mg alloys was studied via ex-situ mini-V-bending tests. The microtexture heterogeneity through the thickness direction of the E-form Mg alloy sheets deformed by different PSs was discussed in terms of deformation twinning and de-twinning during Erichsen tests. The evolution of the microtexture, twin, and KAM (kernel average misorientation) was analyzed via electron back-scattered diffraction (EBSD) technique. The EBSD results revealed how twin bands (TBs) developed at different PSs in the deformed grains made a significant contribution to the localized deformation zones in both Mg alloys under the mini-V-bending process. Mesoscale simulations based on the resolved shear stress (RSS) analysis and crystal plasticity finite element method (CPFEM) simulations were used to elucidate the deformation behaviors in E-form and AZ31 Mg alloys during mini-V-bending. However, a CPFEM based on a random mapping (RM) scheme was used to simulate the heterogeneities of the strain/stress states of E-form Mg alloy sheets through the thickness direction during an Erichsen test.

[KC3-1 | 15:30]
Research on Ti Alloys and Their Applications in Transportation in China: Yong-Qing Zhao, Qian Li; *Northwest Institute for Nonferrous Metal Research*
Keywords: titanium alloy, mechanical properties, application in transportation, development trend

Titanium alloys have been widely used because of their excellent comprehensive properties. This report briefly introduces the R & D status of titanium alloys in China, including some typical titanium alloys, such as high strength Ti-alloys, high temperature Ti-alloys, low temperature Ti-alloys, damage tolerance Ti-alloys, corrosion resistant Ti-alloys, and low cost Ti-alloys. The applications of titanium alloys in transportation were paid great attentions, focusing on the use of titanium in China's C919 large passenger aircraft, bicycles, automobiles, etc.

[KC3-2 | 16:00]
Strain rate sensitivity of titanium and its alloys: Tea-Sung (Terry) Jun; *Incheon National University*

Demands for using lightweight metallic materials such as Ti metals/alloys have progressively increased in many industries. Titanium alloys are typically used as structural load bearing components in aeroengines due to their high strength-to-weight ratio, corrosion resistance and excellent mechanical properties. In service, these alloys are subjected to significant cyclic loading, with high thrust (i.e. stress) excursions during take-off, a load-hold during flight and unloading on landing. The load-hold has been shown to have a significant effect on the fatigue life performance of many dual phase titanium alloys, where a significant hold at maximum load can reduce the number of cycles to failure by an order of magnitude or more when compared with simple 'saw-tooth' load-unload fatigue cycle. This is known as the dwell debit. Recently, it has been demonstrated that failure is dominated by local microstructure in these alloys, including the presence of a rogue grain combination. During the load-hold, stress is shed from a 'hard' grain to a neighbour 'soft' grain and local regions of very high stress form [1]. Time dependent stress amplification at local microstructural regions during this load shedding process near the interface is thought to play a prominent role in facet formation. In practice this effect is mitigated by use of dwell insensitive alloys and careful maintenance schedules but management of this phenomena costs the aerospace industry significantly (~£100m / year). The motivation of this study is to understand the dwell process and in particular to characterise fundamental mechanisms within dwell sensitive Ti-6Al-2Sn-4Zr-2Mo and dwell insensitive Ti-6Al-2Sn-4Zr-6Mo alloys [2]. Electron backscatter diffraction (EBSD) was used to select hard and soft grain orientations within each of the alloys. Nanoindentation based tests using the continuous stiffness measurement (CSM) method were performed to examine rate sensitivity of averaged α and β phases within comparative grain orientations from both alloys, with variable strain rates (i.e. on the order of 10^{-1} to $10^{-3}s^{-1}$) [3]. Local strain rate sensitivity is determined using a power law linking equivalent flow stress and equivalent plastic strain rate. We also have chosen to fabricate 'simple' single colony micro-pillars (~2 μm in width and ~5μm in height) containing different internal microstructures of pure-alpha phase and mixed alpha+beta phase of particular crystallographic orientations to trigger (near-) single slip in ~uniaxial deformation. These micro-pillars have been tested in an Alemnis displacement controlled nanoindentation system within the SEM. Tests have been performed with variable strain rates and load-relaxation tests to extract out rate sensitivities of the different slip systems and to understand the role of the alpha and beta phases and local interfaces [4] To improve fundamental understanding on the strain rate sensitivity of titanium we further have performed macroscopic tension and compression tests with commercially pure titanium, with the aim of investigating the effect of deformation modes (i.e., slip and twinning) [5] and oxygen contents and linking the rate sensitive mechanisms between macro- and micro-scopic level. In this study, an overview of strain rate sensitivity of titanium and its alloys is presented. The experimental approaches shown here present new exciting mechanistic insight into important deformation mechanisms, as well as opening up further studies of new alloy design.

[KC3-3 | 16:30]

Tentative Research on Ti alloy Application in Bogie Component of Rolling Stocks: Gaofeng Quan, Zhengzhi Luo, Yangyang Guo, Houhong Pan; *Southwest Jiaotong University*

Light weighting is a new valuable technological progress in mobile vehicles in last decades. Track transportations are recognized recently as a strategic means of delivery for an independent organization or nation. High strength steels and Al alloys are utilized in structures manufacturing of bogie in rolling stocks are all accepted for reduction in mass. For some key components of bogie structure, steels are too heavy, although Al alloys posses insufficient strength. Ti alloy, i.e., TC4 has very high strength with moderate mass, and should produce a general light weight effect. The additive manufacturing (3D printing) method is used to fabricate a simulant axle box with Ti alloy TC4, for a type of bogie in CR400 EMU model. A simple light weight–cost assessment is made to compare different materials and different manufacturing process in view of life assessment.

[KC3-4 | 17:00]

Twinning-induced Texture Control of Pure Titanium: Jong Woo Won[1], Jea Keun Hong[1], Chong Soo Lee[2]; [1]*KIMS.* [2]*POSTECH*

It is well known that the formation of an intense transverse split basal texture is inevitable in commercially pure titanium (CP-Ti) during conventional cold rolling (CCR) to produce a sheet [1]. Strong rolling texture generally causes deterioration in sheet formability of CP-Ti, giving rise to many limitations on its widespread use in industrial fields [2]. Although twinning has been considered as an effective method to control texture as it causes large-scale change of texture, its applicability to the CCR for CP-Ti is limited. In this study, we propose a two-step cold rolling (TCR) process that enables production of a CP-Ti sheet with weakened and dispersed texture by facilitating twinning-mediated texture control. The TCRed sheet had weakened and dispersed rolling texture (Fig. 1a) compared to the CCRed sheet that had a strong rolling texture in which most c-axes inclined at ±(25°-35°) from the ND towards the TD (Fig. 1b). The TCRed sheet showed high Erichsen value than the CCRed sheet (Fig. 2). This result indicates that TCR can improve sheet formability of CP-Ti. The improvement was attributed to enhanced capability of sheet thinning and reduced planar anisotropy caused by the {11-22} twin texture with its c-axis widely distributed in the rolling direction-transverse direction plane of a sheet. Acknowledgement: This work was supported by the Civil-Military Technology Cooperation Program funded by the Ministry of Trade Industry and Energy, Republic of Korea (16-CM-MA-10).