The 1st Taiwan Symposium on “Fundamentals and Applications of Mo and Nb Alloying in High Performance Steels” was held from November 7 to 8, 2011 in the Taiwanese capital of Taipei. The symposium was jointly organized by the International Molybdenum Association (IMOA), CBMM, NiobelCon, China Steel Corporation (CSC) and National Taiwan University (NTU).

This Symposium was a collaborative effort of leading experts from mills as well as steel research organizations and professionals from academic institutions. The meeting constituted a perfect occasion for discussing future collaboration, exchanging ideas and viewpoints, and fostering genuine critical thinking among the attendees. Although there have been great advances in the steel technology, steel related industry faces the most serious sustainability challenges concerning energy conservation, reduction of CO2 emissions and the generally more efficient use of resources. Vibrant innovation in steel development with tailored properties fulfilling these demands is absolutely vital and the symposium was striving for exactly that goal; of achieving “more for less”.

The one-and-a-half-day meeting presented 15 invited talks focusing on “Metallurgical Fundamentals” and “Product Applications” of high performance steels alloyed with Mo and Nb. The symposium served as a platform for the exchange of experience and expertise in this field. The style of the symposium and the way it was conducted was much inspired by the fabulous Climax symposia held in the 1960s to 1980s. Attention to detail, exhaustive discussions and single sessions allowed the audience to get an in-depth picture on the various effects of molybdenum in steel, and these include quite a lot more than just increasing the hardenability of steel. It was revealed by the various presentations that molybdenum, in its inherent metallurgical functions and in its synergies with microalloying elements such as titanium, boron and notably niobium, could simply not be substituted by any other alloying element. Moreover, several presenters pointed out that the cost argument of molybdenum being “an expensive alloying element” is too simple. The cost of steel is made up by alloying, processing and quality and can hence only be evaluated at the end of the production chain. Examples were given that molybdenum alloyed steels are not only more cost effective to make as compared to molybdenum-free alternatives but also provide a superior property mix.

The various presentations mainly referred to linepipe, automotive and structural applications as these products were of the highest interest for the mainly Taiwanese audience present in the symposium. Even though Taiwan is a small island, its steel production ranks twelfth and, its steel consumption per capital ranks amongst the top 3, in the world. The largest delegation came from China Steel Corporation accounting for the by far largest share of regional steel production. Several other steel companies, such as Chung Hung Steel, Dragon Steel, Gloria Material Technology, Tang Eng Iron Works, Tung Ho Steel Enterprise, Walsin Lihwa, and Yieh United Steel attended. From abroad the Korean and Japanese steelmakers Posco and JFE were represented. As well as these steel professionals, a considerable number of graduate and doctoral students from several Taiwanese universities were present. All together more than 80 attendees participated in the symposium.

Many of the presentations given directly or indirectly addressed the topic of steel for large-diameter pipelines. This sector is of high importance as substantial pipeline construction projects are in progress in the eastern and south eastern Asian region. Dr. J. Malcolm Gray, a true pipeline veteran, gave an overview of 40 years metallurgical development in pipeline steels. By the early 1970s, low-carbon molybdenum niobium alloyed pipe steels was introduced to market and were used for the first time in high strength (X70) steel under arctic conditions in projects such as the Trans-Canada system. More powerful rolling mill technology coming on stream in the 1980s and a peak in the price of molybdenum led to substitution by other alloying elements while some mills sustained their Mo-Nb concepts throughout all those years until today. Molybdenum made its big comeback in pipe steel alloys for more recent projects such as Cheyenne Plains in the USA and especially the Second West-to-East Gas Pipeline in China. Both projects used, for the first time, major quantities of pipe at the X80 strength level. Prof. Chengjia Shang of the University of Science and Technology Beijing was deeply involved in the development of X80 pipe steel at Chinese mills. More than 4 million tonnes of molybdenum-alloyed X80 steel was required to build the Second West-to-East Line. The third line, to be built soon, will be a copy of the existing second line. Prof. Shang explained the specific influence of Mo in the late phase of hot rolling where it controls the microstructure to give superior toughness at very low service temperature. He also projected future developments of X100 strength grades that rely on molybdenum alloying as well. Prof. Sundaresa Subramanian of McMaster University in Canada detailed why certain microstructures in steel lead to superior low-temperature toughness. This really innovative contemplation related to the substructure forming in the steel's microstructure. Molybdenum and niobium in synergy have a great impact in providing a particularly fine substructure that is so beneficial for good low-temperature toughness. Dr. Kim Kisoo sketched Posco's experience of producing high strength hot strip for spiral-welded pipe, which is a more difficult to make than longitudinal welded pipe from plate. This is due to an anisotropy in the hot strip causing the weakest strength to be along the hoop direction of the final pipe. Manufacturing conditions and alloying concepts involving Nb, Mo and Ti have been qualified at Posco to overcome this hindrance and several thousand tonnes of steel have already been produced accordingly. Pipe production and pipeline construction is welding intensive, thus weldability of high strength steel is a key issue. Prof. Jer-Ren Yang of Taiwan National University therefore highlighted the microstructure that can form in the heat-affected zone (HAZ) of weld seams. Although many studies have analyzed the HAZ of pipe steels, considerable confusion exists in the literature, particularly concerning the microstructural morphology in the HAZ. The classification of microstructures on the basis of morphology is of considerable use with regard to the study of structure-property relationships. The contribution highlighted some peculiar morphologies in the HAZ and discussed their possible formation mechanisms. This should allow further optimizing of both alloying design and the welding process for even safer pipelines in the future.

One of the biggest steel consuming sectors in Taiwan and the surrounding region is the automotive industry and hence automotive steel was another prime topic in the symposium. China Steel Corporation is a major producer of automotive steel. Automotive flat steel used to produce car bodies and chassis parts is traditionally not very molybdenum-intensive. However, with increasing demands by the market for higher strength steel, still with good formability, molybdenum is finding its way into this sector. Prof. Hardy Mohrbacher of NiobelCon outlined the potential of molybdenum in multiphase steels where it not only takes care of excellent hardenability, but also simultaneously allows efficient control over the type and amount of various metallurgical phases in the final microstructure. This phase composition makes the properties of either higher strength, better formability or a combination of both. Prof. Matthias Militzer of the University of British Columbia, Canada explained some of the fundamental background and introduced a modelling concept of how the alloying elements, molybdenum and niobium, influence phase transformations. It appears that, even today, not all mechanisms are fully understood, offering an opportunity for future exciting research in that field. Dr. Yoshihiro Hosoya of JFE demonstrated another example of a recently commercialized high-tech automotive steel called "Nano-Hiten". This steel is of the highest strength level and still offers an excellent forming behaviour under the specific forming conditions of stretch-flanging and bending, often used in chassis part manufacturing. The steel contains a high amount of titanium and molybdenum. Molybdenum, here, not only helps to control the phase formation – in this steel it should be single phase ferrite – but significantly influences the precipitation behaviour of titanium that is mainly responsible for the high strength of that particular steel. Dr. Hung-Wei Yen of National Taiwan University explained in more detail how this precipitation mechanism works and presented world-class transition electron microscope pictures, even revealing individual atoms. Prof. Takehide Senuma of Okayama University in Japan presented additional work on how such nano-precipitation strengthened steels can be further improved. One of the fastest growing steel types in automotive body construction is so-called press hardening steel. The steel sheet is heated before forming, to temperatures above 900°C, making it soft and formable. During forming the heat is removed quickly resulting in a quenched martensitic microstructure that is ultra-strong. This material reaches a share of up to 15 percent of the total car body weight in many models all over the world, markedly contributing to sustainability in this sector. Traditionally press-hardening steel relies on an alloy combination of boron and titanium to achieve its hardenability. Dr. Jian Bian of Niobium Tech in Singapore presented an all new alloy concept for this steel by substituting the B-Ti alloying through and addition of Nb and Mo. The latter will give the same hardenability as the former. However, the Nb-Mo concept provides better toughness, higher energy absorption during crash conditions and better resistance against corrosion induced cracking, the last point being of the highest priority for carmakers. Projects with steelmakers all over the world are currently in progress to test and verify this new concept.

The largest tonnage of steel worldwide goes into the many diverse structural applications covering sectors like the construction of heavy equipment, ship building, bridges, skyscrapers, etc.. Taiwan and the surrounding region of the Pacific Rim have the specific challenge of frequent and intensive earthquakes. Steve Jansto of Reference Metals, USA explained the compelling need for development of seismic and fire resistant steels for buildings. Current research and development projects throughout the world are focused on the development of a family of niobium-molybdenum-bearing S500 and S600 grades of bars, beams and plates with superior toughness, fatigue resistance, fire resistance, reduced yield-to-tensile ratio variation within a heat of steel and overall superior performance. The successful high quality production of these Nb-Mo steels with higher strength-elongation behaviour may require slight process metallurgy adjustments to the melting and hot rolling practices to consistently manufacture and initiate the optimal precipitate size, distribution and volume fraction of Nb,Mo(C,N) in these value added earthquake/fire resistant grades. Prof. Hardy Mohrbacher of NiobelCon then considered the synergies of molybdenum with niobium and boron in more detail. These steels are being considered as the material of choice for many advanced applications where yield strength above 500 MPa is required to reduce component weight. Traditionally Mo has been a key alloying element in producing such steels. It became evident that combining molybdenum with niobium and boron delivers a bigger effect than each element's individual effect. In combination with appropriate processing, a wide range of applications can be provided for: truck frames and mobile cranes, offshore equipment, wear and mining equipment, pressure vessels and penstock and many others.

One of the key industries in Taiwan is the electronics sector and Prof. Dong-Yih Lin of National University of Kaohsiung, Taiwan demonstrated that molybdenum alloyed steel is relevant to this important sector. Molybdenum is one of the most effective corrosion resistant elements adopted in stainless steels, which are typically used in seriously corrosive applications like in the semi-conductor industry. To achieve increased hardness of the material surface and to keep its good corrosion resistance a carburizing treatment is sometimes necessary. The dense oxidized passive film on the stainless steel surface makes carbon penetration into this corrosion resistant steel extremely difficult. A special heat treatment procedure has been designed to solve this problem. Several choices for gas atmosphere and a powerful vacuum chamber are provided in this facility. Mo-alloyed stainless steel, SUS 316, has been tested under different heat treatment conditions. Effective carbon penetration, enhancing the surface hardness and corrosion resistance, has been evidenced via microstructural analysis. Molybdenum plays an interesting role with respect to this surface reaction in Mo-alloyed stainless steel.

The symposium was concluded with a visit to the laboratories of National Taiwan University fostering world-class equipment for electron microscopy and microstructural analysis of steels. During the visit, agreements were made for further research and exchange of academic people between the participating institutes. The overall response of all attendees to the symposium, in terms of quality as well as organization, was utterly positive. It turns out that the community still faces many gaps in the knowledge of how alloying elements like molybdenum and niobium function. The symposium revealed the future work to be done and the community is ready to find the answers. Participants clearly wanted to repeat this symposium in due course and Posco committed to support the next event, which was scheduled to take place in Q1/2013 at the Korean Institute of Metals.