Abstract
Development of new steel-based and non-ferrous metal-based materials requires testing of their physical properties to verify their fitness for particular applications. Materials with exact non-standard chemical compositions can be produced effectively in induction furnaces with inert atmosphere or vacuum protection. COMTES FHT is building a vacuum induction furnace for making 20 – 500 kg ingots with specific chemical compositions. Given the broad range of charge weights, two induction coils and multiple crucibles will be used, depending on the particular metal. The furnace is to be used primarily for various types of steels and nickel alloys, and for aluminium and copper alloys, if required. Essentially, the induction furnace can be used for melting various metals in vacuum, inert atmosphere or under overpressure conditions. It allows alloying and microalloying, as well as continuous sampling to be performed during the melting cycle. Temperatures can be monitored using optical pyrometers and immersion probes. The size and the common melting and casting chamber of the furnace provide for a great variety of die casting processes for wrought metals, as well as casting in sand moulds. At COMTES FHT, the induction furnace opens a door for research into novel non-traditional metallic materials.

Keywords: WBCMM – West-Bohemian Centre of Materials and Metallurgy, vacuum induction furnace

1. INTRODUCTION
The ever increasing requirements for tool life and newly emerging processes call for continuous development of new materials and for upgrades of and adjustments to chemical compositions and processing methods for the existing ones. Research and development of new and upgraded metallic materials is one of the key activities and goals of the COMTES FHT Company and the WBCMM (West-Bohemian Centre of Materials and Metallurgy) project conducted by COMTES FHT. This new metallurgical hall constructed as part of this project and its equipment will be used for producing and processing newly designed materials by means of forging, hot and cold rolling and final heat treatment, if required. The equipment at WBCMM will enable COMTES FHT to expand its potential for developing metallic materials, and to conduct pilot testing of newly designed processes. An essential part of any equipment for producing innovative materials is a device for making superior-quality metal of prescribed chemical composition. This can be achieved in a vacuum induction furnace, which is capable to substantially improve the purity and quality of cast metals.

2. REQUIREMENTS FOR VACUUM INDUCTION FURNACE
Vacuum induction furnace protects the metallurgical process from the air by supplying inert atmosphere. This is achieved by placing the entire melting and casting operation in an airtight enclosure capable of generating vacuum or creating inert atmosphere. The furnace in question is required to process charges between 15 and 500 kg. It should offer an option of conducting the melting process without vacuum or protective atmosphere (only for remelting and charge preparation purposes). There are additional criteria given by the furnace’s use in research and development of new materials. Operations that must take place during melting without breaking the vacuum or releasing the protective atmosphere are of great importance:

- microalloying and macroalloying
taking samples for chemical composition testing
- monitoring the melting and pouring temperatures using infrared and immersion pyrometers

Minimum internal height of the mould chamber should be 1500 mm. Given the frequent changes in composition of processed materials, the melting process should take place in replaceable ceramic crucibles from materials that meet specific metallurgical requirements. The crucibles should be quick and easy to replace without substantial interference with the furnace structures. The scope of delivery should include a set of ingot moulds of various sizes.

3. HISTORY OF CONSTRUCTION AND TECHNICAL DATA OF FURNACE

A vacuum induction furnace was an integral part of the metallurgical hall project since 2009, when the idea of establishing the WBCMM Centre was conceived. As part of the market investigation, several reputable producers of vacuum furnaces were addressed in the Czech Republic and abroad. The winning tender was submitted by První železářská společnost Kladno s.r.o., a Czech company with extensive experience in delivering equipment for metallurgical industry.

Key technical data of the furnace:

<table>
<thead>
<tr>
<th>Number of replaceable crucibles</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crucible I capacity</td>
<td>500 kg (150 kW)</td>
</tr>
<tr>
<td>Crucible II capacity</td>
<td>50 kg (30 kW)</td>
</tr>
<tr>
<td>Power supply</td>
<td>400 V 50 Hz</td>
</tr>
<tr>
<td>Power input</td>
<td>250 kVA</td>
</tr>
</tbody>
</table>

Fig. 1: The entire melting plant
4. MELTING PLANT LAYOUT

The core structure of the melting plant is a vertical cylindrical vacuum chamber. It is partially buried in the ground. A removable top lid of the chamber with its accessory equipment is mounted on a supporting structure. The main vacuum chamber is accessible from a platform with furnace controls. The vacuum station and power supply cabinets are located next to the main vacuum chamber. A remote controlled crane with a 6.5 t capacity is available for placing the charge in the crucible and for other service tasks.

4.1. Main Vacuum Chamber

The structure of the main vacuum chamber consists primarily of a vertical 3000 mm-diameter cylinder with the height of 2800 mm. The main vacuum chamber houses a crucible with the furnace coil and a space for placing ingot moulds. The melting and pouring stations are therefore located within a single chamber. The purpose of the pouring cup located between the furnace coil and the ingot mould is to direct the flow of the molten metal to the centre of the ingot mould and to hold a strainer for filtering the melt, if required. The axis of the crucible is in the same location for both 50 and 500 kg charges. It is thus easy to inspect the process through the sight glass, which is aligned with the alloy addition device, sample taking equipment and the infrared pyrometer. In case of open-furnace melting without protective atmosphere, the vacuum chamber is only covered with a walkable top cover that allows handling, sample taking, temperature measurement and other required tasks to be performed.

Fig. 2: Pouring equipment inside the vacuum chamber

4.2. Vacuum Chamber Top Lid

The double wall water-cooled top lid is suspended from a structure which allows it to be set aside and clear of the vacuum chamber for the purpose of charging or for crucible replacement. The top lid includes an alloy addition chamber located in the place above the crucible. Besides adding the required prealloy, the chamber is also used for taking samples. The prealloy is inserted in the alloy addition chamber. After vacuum is generated using an auxiliary pump, the lock between the alloy addition chamber and the vacuum chamber opens. The charging bucket is then lowered above the surface of the molten metal and the prealloy is released into the melt. The sight glass in the side of the top lid enables the melting process to be observed and recorded on camera, if required. The alloy addition chamber houses rods with immersion thermocouples and the device for taking samples for chemical analysis. The top lid is held in position by a bayonet lock,
which secures and seals the top lid for the purpose of overpressure melting (up to 0.2 MPa). The lock is controlled by a hydraulic mechanism.

![Image of furnace top lid]

**Fig. 3**: Furnace top lid

![Image of alloy addition chamber with charging bucket]

**Fig. 4**: Alloy addition chamber with a charging bucket

### 4.3 Vacuum System

The entire vacuum system consists of the main loop and the auxiliary loop. The auxiliary loop places the alloy addition chamber under vacuum prior to opening the gate valve leading to the main vacuum chamber. This loop features a single vacuum pump, which brings the chamber pressure down to approx. 200 Pa. The main loop comprises two rotary vane pump and two Roots-type pumps with a bypass valve. The combination of these pumps provides a working pressure of 10 Pa. The unit also includes filters for purifying the pump oil and an air filtration unit cleaning the exhaust air from the furnace.
The vacuum of 10 Pa guarantees correct metallurgical reactions. On the other hand, melting at an overpressure of up to 0.2 MPa improves uptake of elements from the furnace atmosphere by the melt, as well as the cast ingot quality.

4.4 Pouring Options
Available pouring options are only limited by the size of the pouring area. The molten metal can be cast into ingot moulds, sand moulds, as well as other types of moulds. Multiple castings can be poured, either one-by-one or simultaneously. The basic set of ingot moulds includes moulds for conventional forging ingots of 50 and 500 kg weight and one 500 kg mould for feedstock for rolling. The main vacuum chamber depth is sufficient for future adaptation for semicontinuous casting applications or for casting tall cylindrical ingots.

Fig. 5: Schematic representation of the vacuum system

Fig. 6: Schematic representation of the ingot pouring process
4.5 Furnace Temperature Measurement

The temperature of the melt in the crucible can be measured by two independent instruments: an immersion temperature probe and a contactless infrared pyrometer. Both systems will have to be calibrated for various materials and conditions in order to eliminate their deficiencies. Immersion temperature probes by TERMOSONDY Kladno s.r.o. provide accurate measurement. Combined probes, while allowing samples to be taken and oxygen activity to be measured, offer only a small number of measurements over their life. Replacement of such probes requires that the alloy addition chamber is adjusted and reevacuated, which extends the melting times and decreases the furnace operation efficiency. This drawback can be eliminated by synchronising the measurement with the optris® **CT ratio 1M** infrared pyrometer by the German company OPTRIS GmbH capable of multiple measurements. However, its accuracy is poorer due to the effects of impurities floating on the surface of the molten metal and the environment above the melt. Combining the measurement by pyrometers and immersion probes allows accurate data to be gathered on the entire melting process and high repeatability in preparation of unique melts to be achieved.

![Immersion temperature probes](image1.jpg)

**Fig. 7:** Immersion temperature probes supplied by TERMOSONDY Kladno s.r.o.

![Infrared pyrometer](image2.jpg)

**Fig. 8:** optris® **CT ratio 1M** pyrometer by the German producer OPTRIS GmbH
4.6 Taking Samples and Chemical Compositon Testing
When a combined probe is installed, temperature measurement by immersion can be combined with taking sample of the melt. The sample can be removed from the alloy addition chamber and its chemical composition can be measured. This operation also enables oxygen activity in the melt to be determined. The furnace operator can use the results of these tests to adjust the melt chemistry or to finish the melting process. Chemical composition is measured in the Q4 TASMAN optical spectrometer. The gas content can be found using the G8 GALILEO combustion analyser by Bruker-Elemental, JUWE division based in Germany.

5. CONCLUSION
At present, the furnace is being installed and tested. The entire installation will be completed by the end of 2012, after which trial runs for both crucibles will be performed. The furnace, as well as the entire metallurgical hall, will be available for regular operation at the beginning of the year 2013.

ACKNOWLEDGEMENT
The results presented in this paper were achieved under the project “West-Bohemian Centre of Materials and Metallurgy” CZ.1.05/2.1.00/03.0077 co-funded by European Regional Development Fund.

LITERATURE