Danieli Converter Revamping Technology: Highlights and recent developments in converter design

Since the startup of Danieli Converter Technology in 2011, several BOF revamping projects have been realized and converters have been successfully brought into operation. In addition to keeping costs at a minimum, the most important tasks for a revamping project are:
Enlarging the inner volume, whilst reusing as much of the existing equipment as possible.

- *Maximizing the life time of the converter vessel.*
- *Shortening the delivery time while maintaining quality.*
- *Keeping the shutdown time during erection to a minimum.*

Some recent examples which fulfill these requirements are presented, along with two special topics:

- *Revamping a converter by reusing an existing trunnion ring.*
- *Developing a measurement system for online monitoring of the vessel shell temperature and deformation.*

Reusing an existing trunnion ring is not a regular requirement, but sometimes it gives added value for steel plants. Such an approach has been successfully applied to a 160t BOF in Ukraine and will be realized for two 65t BOFs in India. For this purpose, Danieli Corus have developed a special technique which avoids high demanding welding, or machining on site.

Danieli Corus has already successfully implemented sensors to measure vessel temperature in converter plants. For measuring the deformation of the converter over time, Danieli Corus has further developed this sensor. The most challenging aspect was to create a sensor which can operate at ambient temperatures of more than 250°C. At these temperatures, electronic equipment cannot be applied and a new, innovative solution was found.

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INTRODUCTION

In 2011, Danieli entered the converter market starting with Danieli Linz Technologies and, since 2018, with Danieli Corus. Currently, 18 converters, ranging in size from 65t up to 350t, have been revamped worldwide. Eight have already been installed, with others in the engineering or construction phase. An overview of these projects is shown in *Figure 1*.

Various challenges have to be solved in the revamping business, such as maximizing the inner volume of the new converter vessel, minimizing pre-assembly on site and introduction of additional features, or new technologies. Increasing the inner volume is subject to many limitations, such as maintaining the absolute position of the top and bottom of the vessel shell, as well as the bearing separation distance. The mouth diameter and the dimensions of any detachable bottom should also not be changed. Consequently, all converter revamping projects are very specific and tailormade solutions must be developed.

There are not only technical issues to solve. The introduction of new features, or technologies are sometimes strongly dependent on personal experience, or plant operating philosophies, such as the use of thermo-mechanical rolled steel grades for the vessel shell, or water cooling of top cone and trunnion ring. Despite these restrictions, newly installed converters have been further improved, particularly in Brasil.

These improvements include:

- Special Cr-Mo-shell material.
- Water-cooled top cone.
- Ari-cooled trunnion ring and vessel barrel section.
- Online Temperature monitoring system.

In this paper, special topics have been selected to give a

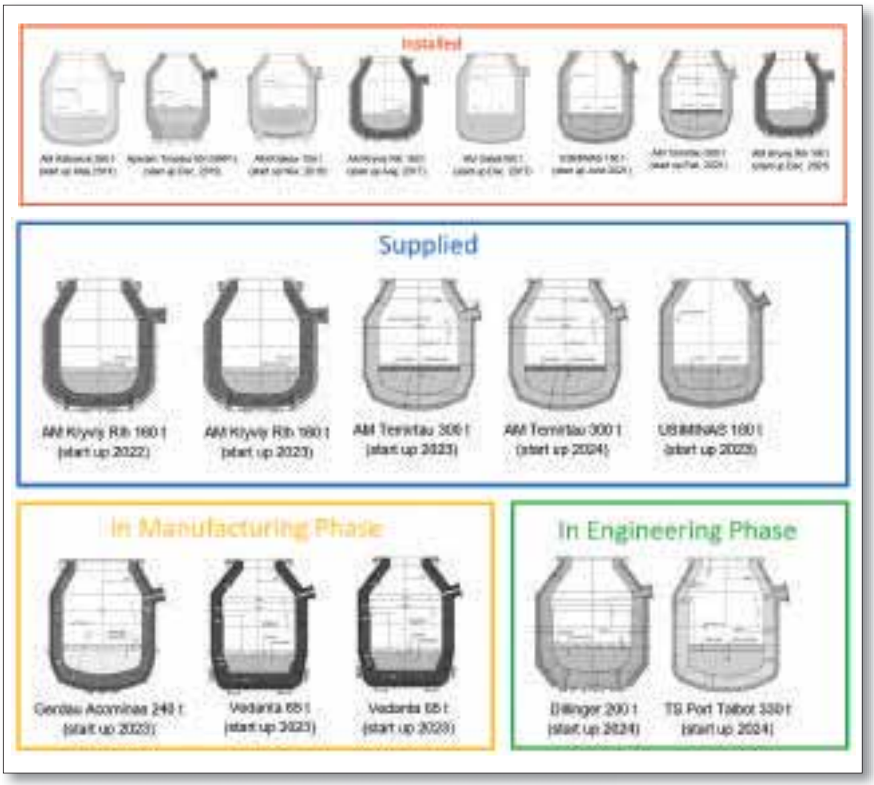


Fig 1 **Danieli Corus converter revamping references**

better insight into interesting details of some converter revamping projects.

CONVERTER SHELL MATERIAL

The minimum requirement for a converter material is achieved by the P355GH (ASTM 516) steel grade, which has moderate mechanical properties, creep resistances up to 400°C and is relative easy to weld. The most common and well proven converter shell material is 16Mo3 according to EN 10028-2 (ASTM A 204). This material has good mechanical properties at elevated temperatures and creep resistances, both of which are guaranteed up to 500°C. Welding has to be handled with care but it is not very demanding.

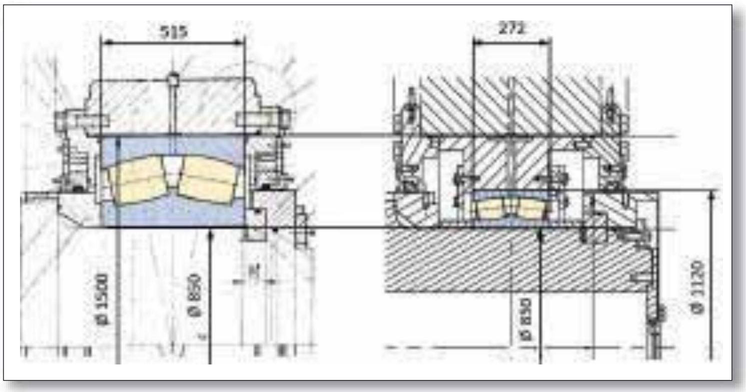
For higher temperatures, or special customer requirements, the next highest steel grades are Cr-Mo-alloyed steels, such as 13CrMo4-4 (ASTM A 387 Gr.11), or 10CrMo9-10 (ASTM A 387 Gr.22). Such materials have higher mechanical properties and greater creep resistances than 16Mo3, but are highly demanding in terms of welding. In these cases post weld heat treatment is obligatory. This is challenging for manufacturing and assembly on site, and even more so for repairs during production. Consequently, it has become more common to combine different steel grades in one vessel shell. Some examples are shown in *Figure 2*.

Alternative converter materials include SEV295mod, deployed at Nippon Steel, and P420MHT, in use at Dillinger Hütte. Both of these alloys are thermo-mechanically rolled steel grades, with excellent mechanical properties and creep resistances. n the case of P420MHT the latter is guaranteed up to 450°C. However, in worldwide converter applications, these grades can be considered as 'exotic'. The major reasons are that most steel plants cannot guarantee to keep the vessel shell temperature under a level of 450°C and not even 500°C during the complete life time of the converter. There is always the risk of local overheating, which would cause these steel grades to lose their 'memories' and ultimately deform. As a result, the performance would be significantly reduced. In reality, SEV295mod is used in Japan and some plants in China, whilst the P420MHT is used in some plants in Germany. Other materials such as P460NH, NAXTRA and similar, are fine grain pressure vessel steel grades with high mechanical properties up to 450°C, but, based on their characteristics, they do not have guaranteed creep resistance and are consequently not common.

REUSING THE MAIN BEARING HOUSING

A common approach when revamping a converter vessel is to change the main bearings, but to reuse the housings. This ▷

Ⓐ Fig 2 **Steel grade combinations in a vessel shell (temperature resistance and life increasing L to R)**



Ⓐ Fig 3 **Main bearing arrangement before (L) and after (R) revamping**

Ⓐ Fig 4 **Trunnion ring adoption bracket**

is usually not an issue, since the housings are very robust and can last longer than the converter life time. For a revamping project in Ukraine, the existing 160t converter was based on an old but very robust design. In particular, the bearings had huge dimensions, with an inner diameter of 850mm, an outer diameter of 1500mm and a width 515mm. Modern bearings for such a converter size are much smaller and a design was produced with an inner diameter of 850mm, an outer diameter of 1120mm and a width of 272mm. The new bearing also had to be designed for oil lubrication. With this approach, the capital cost of the bearings could be reduced significantly, which was beneficial in funding a spare bearing. The comparison of the old and new arrangement is shown in *Figure 3*, right.

REUSING THE EXISTING TRUNNION RING

Under certain conditions, it makes sense to reuse an existing trunnion ring. In the same plant in Ukraine described earlier, three converters were to be revamped. Two with a new trunnion ring and one by reusing the existing trunnion ring, which was delivered to site in four pieces. The challenge was in connecting the horizontal suspension element to an existing trunnion ring. Usually, these suspension brackets are welded and machined together with the trunnion ring at the manufacturer's workshop. For the vertical elements there was no change at all, because those elements are welded as pre-assembled sets to trunnion ring and vessel shell on site. The objective was to minimize the adaption of the existing trunnion ring as much as possible. To address this, Danieli Corus supplied so-called 'trunnion ring adoption brackets'. Those consist of a part of the trunnion flange plate, with fully machined suspension brackets already welded on (*Figure 4*).

All four parts of the existing trunnion ring were welded together. Subsequently, the top flange in the area where the new trunnion ring adoption brackets are located was opened and the old horizontal suspension brackets on the other side were removed (*Figure 5*).

The next step is the alignment of the new trunnion ring adoption brackets, followed by preheating and welding. Due to the fact that the trunnion ring adoption brackets are subject to high loading, welding to the existing trunnion ring was by back strip welding from the outside only and post-weld heat treatment was not required. However, the back strip welding of the diaphragms was done from inside the trunnion ring. This simplified the onsite installation procedure and gave a significant reduction in both time and cost. However, the welding sequence had to be developed and optimized to prevent any distortion of the fully machined trunnion ring adoption brackets, ensuring proper shape and alignment (*Figure 6*). An analogous approach is planned for another project in India, were an existing trunnion ring, which has been already in operation for some years, will be reused.

ONLINE MEASUREMENT OF VESSEL SHELL TEMPERATURE AND DEFORMATION

The online temperature measurement system Q-Temp 2.0, has already been successfully installed on a new 180t BOF in Usiminas Ipatinga in Brasil (start-up in 2021), as well as on an existing 180t BOF at voestalpine Linz in Austria (start-up in 2019). This system is installed inside the trunnion ring **[1] [2] [3]**. The good performance of this system begat another installation on the second BOF at Usiminas and for a 240t BOF in Gerdau Ouro Branco Brasil.

Currently Danieli Corus is working on the next generation technology, which allows for online measurement of the relative deformation of the vessel shell versus the trunnion ring. This deformation is the most relevant because it reduces the lifetime of the converter. The task was to measure the relative deformation, in the range from 0 to 150mm with a tolerance of +/- 1mm. This may seem straightforward, but as usual the devil is in the detail. All measurements have to end up in an analog, or digital signal which can be further digitalized. For the temperature measurement a hermos couple can be applied, the output of which output is already an electrical signal that, along with the cables, can withstand a temperature of more than 1000°C. For the deformation however, no sensor is available which can withstand such high temperatures. All commercial electronic sensors have a limit of 80°C but the temperature at the converter shell, or inside the trunnion ring can reach more than 250°C. Consequently, a sensor had to be developed which is not based on any electronics.

The objective of this development is to have a sensor that provides online electric signals which are proportional to the vessel shell temperature and to the deformation. The sensor must be robust enough to withstand temperatures of more than 250°C and it should be possible to install on both, an existing and a new converter. The solution was found by using technologies from times before electronic were developed, following the strategy of keeping things as simple as possible. The new sensor under development consists of and electric resistance coil and a mechanical amplifier, which enlarges the vessel deformation by a factor α, to reach a certain resolution. Currently the prototype is under test within the laboratories of Danieli Corus. After an optimization period it will be tested on an existing converter, under real operation conditions.

CONCLUSION AND REMARKS

Danieli Corus has proven its competence in the field of oxygen steelmaking, in particular for converter revamping projects.

Fig 5 **Existing trunnion ring with partly opened flange plates**

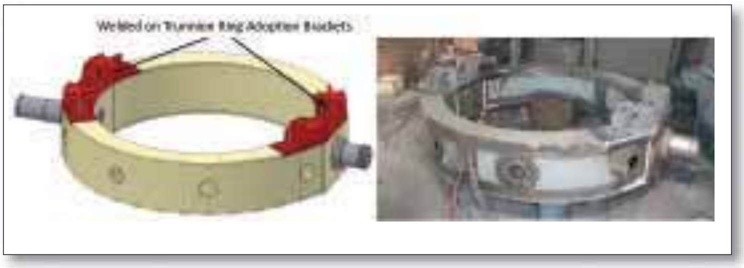


Fig 6 **Welded on trunnion ring adoption brackets into existing trunnion ring**

Danieli Corus has developed special approaches for:
- Reusing existing bearing housings in combination with state-of-the-art bearings.
- Reusing, or adaptingof existing trunnion rings, to avoid onsite machining, and to reduce welding and post weld heat treatment.
- Developing the well proven online temperature measurement system of the vessel shell by adding an onboard online deformation measurement system. MS

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