TUNDISH STOPPER OPTIMISATION[1]

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Abstract
In steel continuous casting operation, the Tundish Stopper is an essential component. Every aspect of its functionalities has been studied in order to optimize performance and cost. In addition to the material itself, attention has been focused on the general design, connections and fittings relating to argon injection, and reliability of gas flow and nose redesign. The design has been reviewed completely in order to get a lighter piece, still giving or even increasing its overall mechanical resistance. The new overall design, called “PROFILER”, allows a weight saving from 15% to 35%. The argon connection called “ARGOROD” has been optimized and gives an extremely tight system with gas loss lower than 0.2 L/Min. A special way of injecting gas through a calibrated pipe, inserted in the nose, shows a very predictable backpressure during pre-heating and casting. The new sophisticated nose design, named “RIPPLE” has been thoroughly checked to get an optimized flow pattern at the shroud entrance. New material has been developed including low graphite material with very good erosion resistance for the most of the steel grades, including aggressive types.
Key words: Continuous casting; Flow control; Tundish stopper.

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Introduction

This study focuses on steel continuous casting stoppers specific aspects optimization in order to:

- Optimize the weight by getting a lighter piece.
- Get a reliable injection system through the stopper nose
- Improve the seal of all connections.
- Develop new nose design in order to optimize the flow.
- Get special mixes to withstand aggressive steel grades

Stopper Weight/Strength Optimization (Called: "PROFILER")

Historically, stoppers are cylindrical. In most cases, stopper body erosion is not an issue. Most existing stoppers are oversized when considering the stress faced in use. The way to look at the stopper resistance is to clamp the metallic rod-end in a fixed position and apply a lateral force in the nose area (simulating the re-centering of the stopper on the seat in its casting position). The weakest area is obviously the area close to the rod-end, which faces the maximum stress. Below that area, the stopper is oversized. The cylindrical shape is not optimized in terms material volume.
VESUVIUS developed and adapted software programs, which calculate the appropriate sections to ensure an optimization of the material necessary to resist the stress faced in use. The shape has also been optimized taking into consideration the stopper nose diameter, which is adapted to suit the seat with which it will work.
Naturally safety factors have been taken into account in the development of the programs in terms of minimal refractory thickness and manufacturing abilities. Using these programs showed that in many cases it was possible to save a significant percentage of material, whilst keeping or even increasing the overall resistance of the stopper. After thorough laboratory validation trials, the field evaluations have been successful and confirm the validity of this Weight/Strength Optimization Program.
The potential savings vary from 15 to 35% in weight which, in our current environment, in terms of price policy and health and safety factors for workers (handling) is extremely valuable. Typical design is shown on Figure 1.

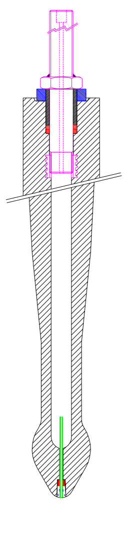

Figure 1: Profiler Scheme

Tighter Connection

The classical UNIROD (Figure 2) is not perfect in terms of tight connection for following reasons:

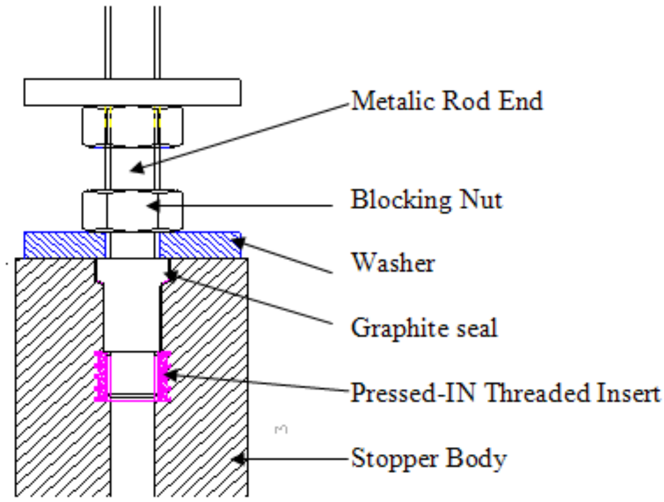

Figure 2: UNIROD Scheme

The difference in thermal expansion between the body material and the metallic rod is such that during preheating and use, the connection eventually slackens. The thin graphite seal gives to the system a very limited elasticity, leaks may also occur in use mainly due to vibration and lateral stopper movement in regulation. Slowly the stopper loses its original tight-fit and the backpressure goes down. (Figure 3)

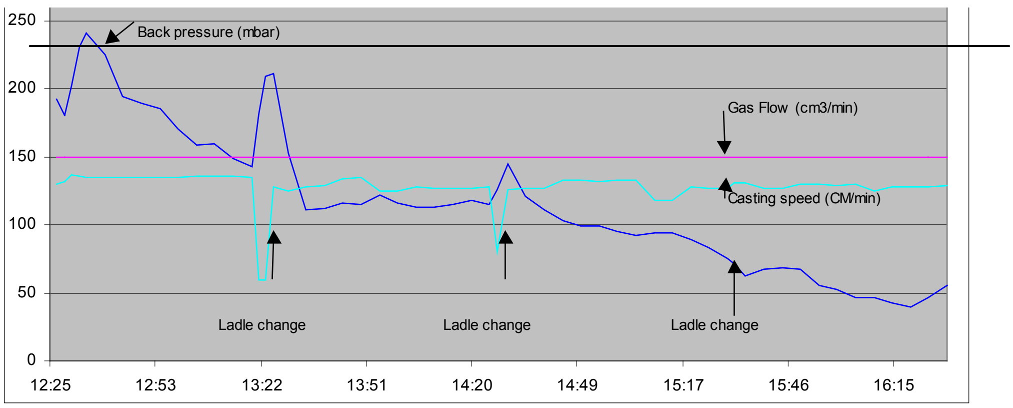

Figure 3: Back pressure going down with standard connection.

In order to solve those issues, a new connection called ARGOROD was developed. A very high thermal expansion sleeve is introduced in the system to compensate for the difference in dilatation between the metallic rod and the stopper body. The method for calculating the dimensions is made in such a way that the sleeve will maintain the graphite seal in constant compression at all temperatures. The thickness of the seal has been considerably increased to assure an improved tightness in every way, including radial, and gives additional elasticity to the whole system.

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This new connection (Figure 4) is now in general use in several Steel Plants throughout the world.

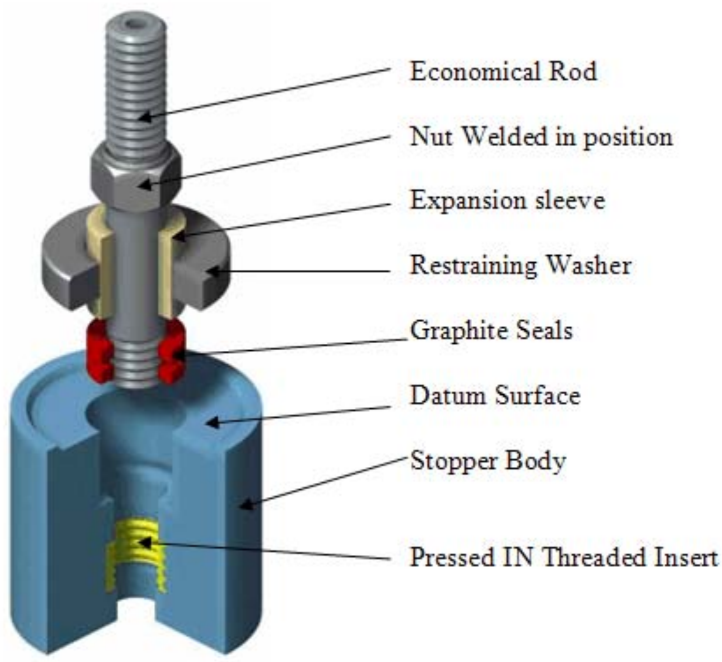

Figure 4: Argorod Scheme

In the ARGOROD system, all the dimensions and tolerances are calculated to assure easy assembly and to assure the tightness of the connection through correct compression of the graphite seals. A Datum surface (reference) is pressed into the stopper head. The quality of the graphite seal has been carefully chosen to give the best ratio between elasticity and plasticity. A special gauge is used before assembling to check the correct position of the expansion sleeve.
In a first step, when screwing the metallic rod into the stopper, the sleeve is pushed down against the seals, compressing them. In a second step, the washer comes in contact with stopper datum surface. All are then blocked fixed rigid in position without altering the seals compression.

Injection System

It is very well known to inject argon gas through stopper nose. What the user needs is to inject a controlled and given flow through the stopper nose, getting an acceptable backpressure. Most users look for a positive backpressure (preventing air aspiration), usually as low as possible (around 0.1 - 0.3 bar), to prevent leaks in the argon installation. The easiest way is to have a hole in the stopper nose, usually 5mm (it is extremely difficult to produce a smaller hole in manufacturing). However such stoppers can easily show negative back pressure and therefore are prone to air aspiration if the gas installation shows any defects.
Another solution is to introduce in the stopper nose a porous plug, which will give a positive backpressure in the stopper. This solution however gives some problems as, despite much effort to control the plugs, the permeability varies significantly from plug

to plug and also with temperature, so it becomes very difficult to predict which backpressure will be obtained in use.
To overcome this inconsistency, a reliable system for gas injection has been developed (Figure 5)

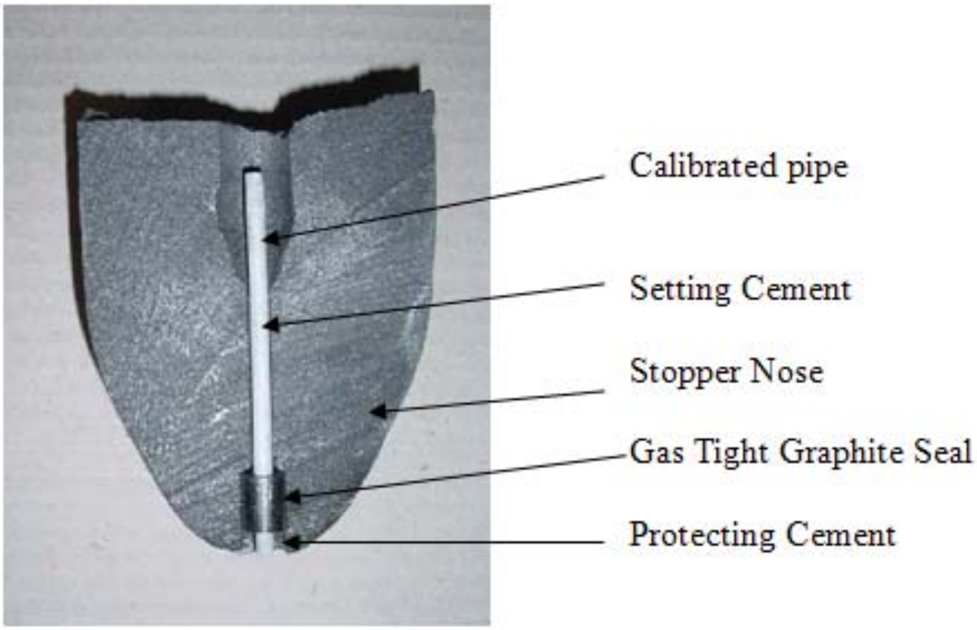

Figure 5: Picture of Actual Calibrated Pipe

A calibrated pipe (given constant diameter) is cemented in the stopper nose. A graphite seal secures the tightness. The pipe goes quite deeply inside the stopper to avoid any particles or dust from falling in the hole and block it. This system is very efficient and reliable.
Two operational types can be proposed. A low backpressure (>0.7 bar) gives a gas flow with a speed lower than sound. This subsonic flow affects the backpressure, which varies according to the pressure in the casting channel (generally negative). The user can see the variations of the process, which will show on the backpressure evolution. In that case, the overall argon system needs to be tight and very well controlled including the argon box and all the different pipes.
A higher backpressure is achieved when the gas is flowing at sonic velocity in the calibrated pipe. In such a case, the backpressure is constant irrespective of the pressure in the casting channel. With such a system, the flow can be regulated directly from the line pressure regulation, the possible leaks in the system will not effect the flow through the stopper nose into steel.
The choice of the calibrated pipe diameter will be calculated according the users request and conditions. It is not always simple to theoretically calculate the right diameter and trials are usually deemed necessary to establish the best diameter to use. However, once established, the backpressure control becomes very reliable and the superiority of such a system versus existing ones has been proven in the field. (Figure 6)

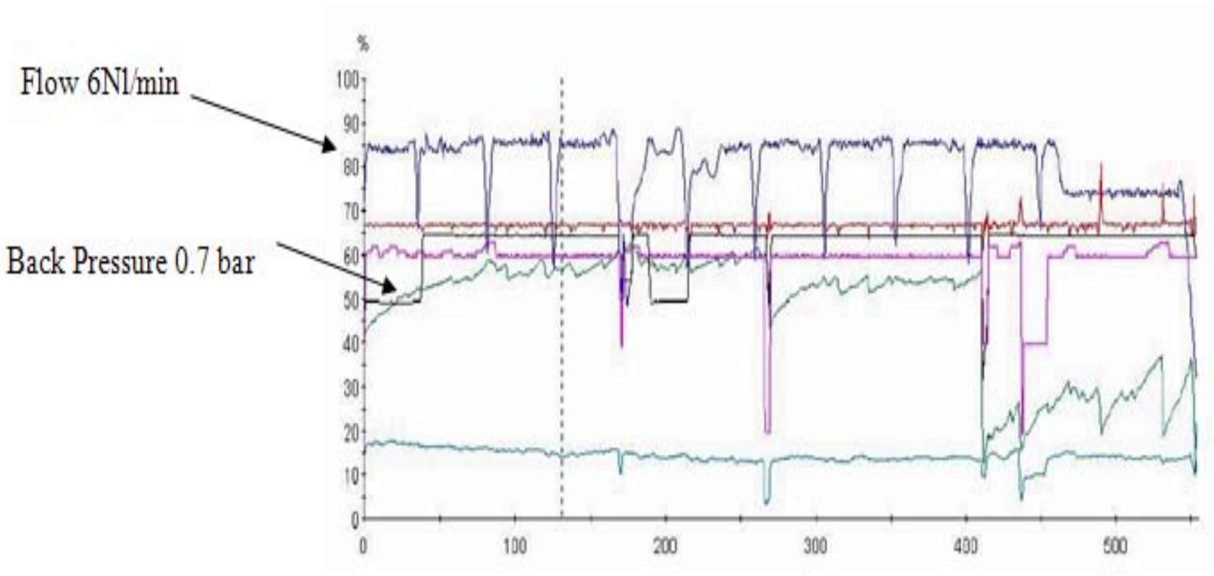

Figure 6: Flow and Backpressure behavior

The New Stopper Nose Design "RIPPLE STOPPER"

For improving stopper flow regulation and reducing non-metallic inclusion deposition, VESUVIUS through ADVENT capabilities in Canada, has developed a Ripple Stopper nose profile that has proven to be successful in several Steel Plants (Figure 7). Its design shows:

1 - Step at the entrance prevents deposition by locally altering the flow and changing the feeding angle.

2 - Ripples located downstream of the regulation area, they prevent the formation of large scale eddies that may affect flow stability in the mould.

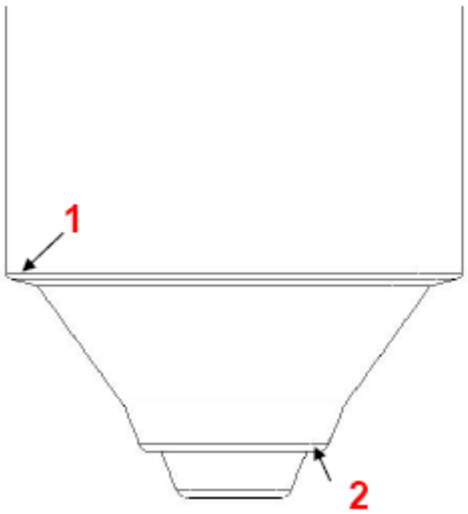

Figure 7 Ripple nose general scheme

The Ripple Stopper design improves the flow regulation trough less mold level sudden fluctuations and reduces the large mould level fluctuations as noticed on Figure 8:

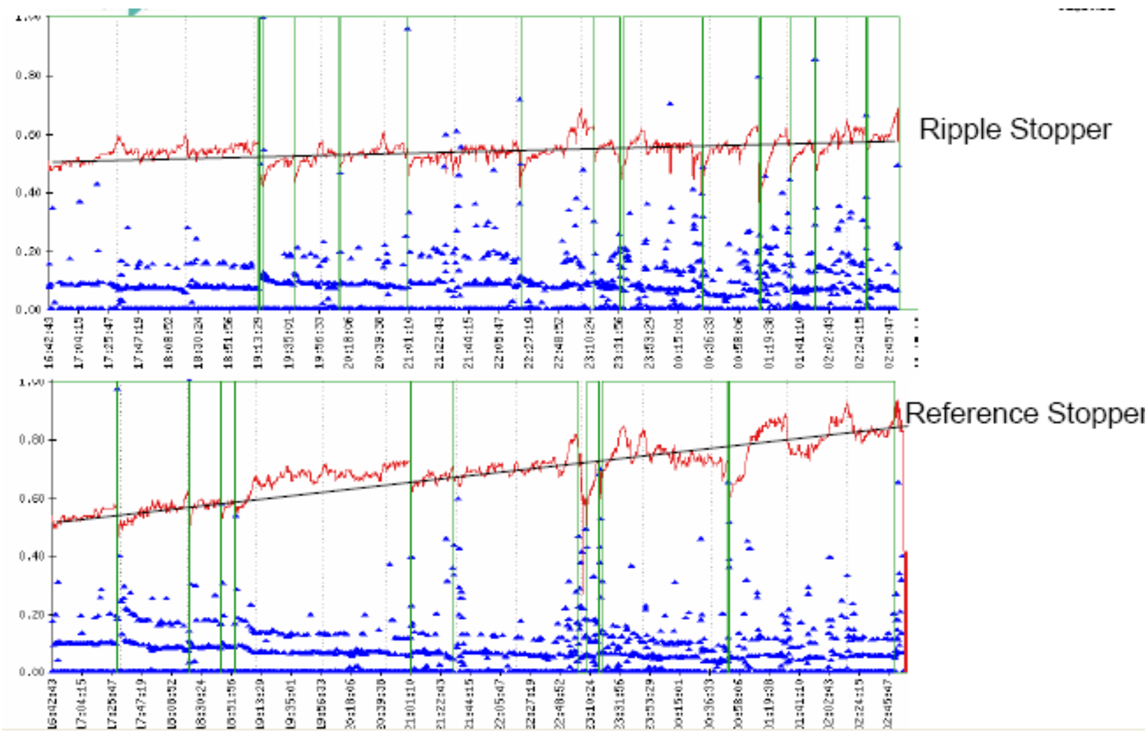

Figure 8 Comparison of stopper position with a ripple nose versus a standard multi-radius nose

With the current system, high velocity and low-pressure regions, promoting the vaporization of volatile species in both refractory and steel causing erosion in certain regions, as well as fluid flow phenomena that promote oxide formation and deposition in other regions, have been identified. The Ripple Stopper System promotes pressure, turbulence and velocity distributions, along the refractory surface approaching the throttle gap, which retards refractory erosion and non-metallic build-ups. Thus flow regulation can be improved and process upsets such as sudden flushing, or stopper rod hunting can be alleviated. Steel flow downstream of the stopper flow regulation region (i.e. flow in the SES and mold) is improved and better stabilized using the Step-Ripple System.

Figure 9: Ripple Stopper Nose Design

High Performance Mix Generation

A new manufacturing technique has been developed to place low graphite (< 3%) mix, very resistant materials in layers of 4 – 25 mm thickness at the stopper nose area where it would be required to cast very aggressive steel (Figure 10). Another back-up material behind is applied to assure a smooth transition between the hard, erosion resistant surface layer and the stopper body material by decreasing significantly potential stress created through co-processing material with different physical behavior.

Today, due to these new stopper developments, we can cast many aggressive steel grades like high oxygen or free cutting steel, which, in the past, could only be cast using a “slide gate system”.

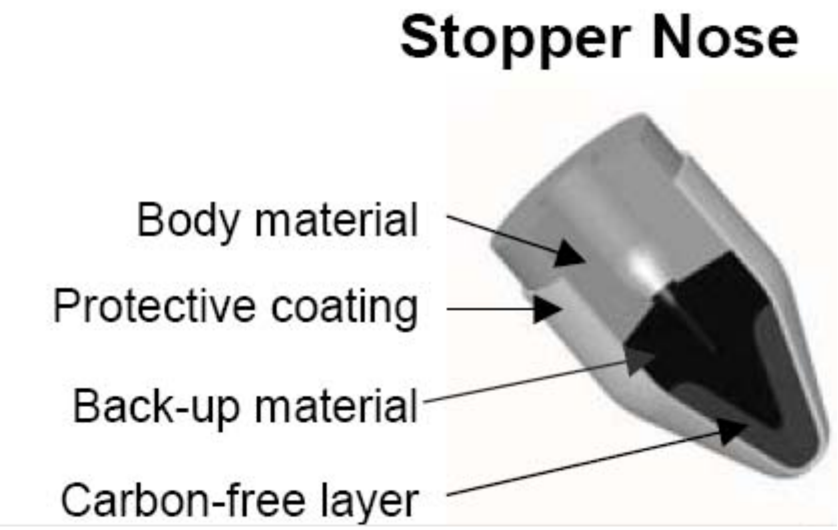

Figure 10: Multi-mix high performance layer

The composition of atypical high resistant MgO mix is
Chemical analyses on oxide base:
Silica: 4.2% // Alumina: 9.8% // Calcia: 0.8% // Magnesia: 81.4 // Boron oxide: 3% // Zirconia : 0.4% // Loss of Ignition: 1.6%
Physical properties:
Modulus of rupture at room temperature: 10.3 N/mm²
Apparent porosity : 12.6%
Bulk density: 2.67 g/cc

BIBLIOGRAPHY

1 Optimisation des tampons de coulée. - F.N. Richard – Présentation ATS (Paris, 11-12 décembre 2001)