

## **“FMF BASE MODULE”: No Electric Power Steelmaking with FMF**

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### **Abstract**

Steelmaking is highly influenced by the availability of raw materials and energy. Indian steelmaking, in particular, is facing challenges in terms of availability of desired quantity, quality and price of coal and iron ore, & significant scrap shortage and high electric energy prices. In this scenario several steelmakers have found in the use of hot metal in their EAF a convenient alternative, which is increasingly gaining popularity. However, it is known that in the future scrap & DRI will gradually revert to be the primary raw material for steel mills, moreover scrap based steelmaking has a lower overall costs and environmental footprint. Further it may be noted that India is the world’s largest producer of sponge iron with a host of coal based units, located in the mineral-rich states of the country.

Therefore, Tenova has developed a new furnace concept, specifically targeted to steelmakers that currently use a significant amount of hot metal in their charge mix, yet ready to move or return to scrap / DRI / Pig Iron based steelmaking: the Flexible Modular Furnace (FMF). This solution is also suitable for those steelmakers that are looking for a transition from BOF to EAF based steelmaking and for those EAF steel shops that want to increase the hot metal percentage in their charge mix to cater the present situation.

In its simplest form, the so called “Base Module”, the FMF can be configured for hot metal based steelmaking and, according to the characteristics of the charge, it can efficiently operate without electric power (similar to a BOF); the electric power module (transformer, electrodes etc.) can be installed later on, as the most convenient charge mix changes, introducing larger amounts of scrap and DRI, according to the market. In its final configuration, the FMF can be transformed into a fully featured Consteel® EAF with continuous scrap feeding and pre-heating.

**Key words:** Flexible steelmaking, Hot metal, EAF, No electric power, Productivity, Opex

## Introduction

In the recent years steel business experienced the shifting of profitability toward the owner of raw materials in such a way that steelmakers have been forced to adapt having a tight market price and an unstable cost basis (ref. [1]). In India the high availability of virgin iron, higher power cost, coal crises and the immaturity of scrap market led the steel industry to reduce the EAF based production and to increase the amount of hot metal in the EAF still in operation. While the global raw material and energy instability will remain a major condition, the general trend of steelmaking is moving toward more environmental friendly and less energy intensive processes and so to the increasing use of scrap / DRI / Pig Iron percentage in the charge mixes. Tenova developed FMF (Flexible Modular Furnace) solution summarizing the state of the art of DRI / scrap-based EAF and the working practices adopted in those EAF that use high Hot Metal percentage in the charge mix. (ref. [4]).

This study presents FMF main equipment, a process simulation example and the related economic considerations.

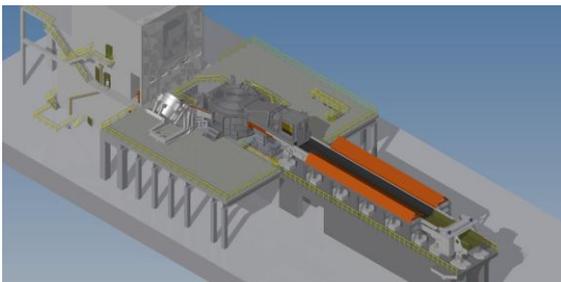
We call it as Flexi Modular Furnace, FMF which is capable of adopting different modules viz.,

- Base Module (for high hot metal percentage in the charging mix) - No Electrical Power needed in this configuration
- Add-on modules for a wide range of different scenarios viz. marginal to substantial increase of the scrap / DRI / pig iron in the charge mix.

The unique concept relevant to the “Base Module” is based on 3 main pillars:

- Shell and refractory innovative and customized design.
- Continuous and controlled feeding strategy in order to tune the pouring of the hot metal ( and all the other possible raw materials) into the furnace shell.
- KT lance technology (high efficiency) and KT lance multipoint injectors customized location.

## Shell part



Tenova FMF is a modular concept of smelting furnace that can be developed starting from core equipment called Base Module by means of specific add-ons following an “investment on demand” approach. Each module is designed with specific features in order to fit the requirements of the charge mix (ref. [3]).

**Base Module is designed for high hot metal percentage in the charging mix and includes:**

Complete Foundation design that is the basic template to build up all the modular configurations of FMF and is already well-structured taking into account the major upgrades such as transformer and electrode package.

Tilting platform that follows the standard Tenova EAF concept and includes control elements such as weighing system.

Lower Shell that is made by two sections: the standard Tenova EAF Lower Shell and the so called Intermediate Shell. Such design aims to increase the refractory level in order to improve the furnace performances and lifetime during high reactivity processes in what we call converter mode.



**Figure1 : FMF - Base Module Concept Design - Explosion view**

Upper Shell that matches with the modular development of Lower Shell and is “shorter” than a standard EAF (see Figure 1) in order to maximize the refractory lined volume.

FMF Water cooled roof that is re-shaped to allow a better control of the reactions between off gases and fresh air (refer to Conceptual design Figure 1).

Off-gas analyser that prevents explosions in the fume dedusting system and monitors both process and chemical reactivity into the furnace.

No Electrical Power is needed in FMF Base Module configuration and consequently several investments typical of a “standard EAF” can be avoided (i.e. electrode arms, secondary system, transformer, hydraulic unit portion for electrode regulation and related auxiliaries).

### **Add-on module Consteel®**

According to recent experiences a small Consteel® that works as temperature regulator is a unique technology in order to use the FMF in converter mode. There are mainly 2 advantages:

- Consteel® allows to add scrap, ferroalloy, lime, dololime whenever during the process and without affecting the productivity and to regulate the bath temperature and therefore promote dephosphorization (~1550°C)
- Consteel® minimizes the number of roof opening affecting positively both energy saving and productivity.

Continuous charging by means of Consteel® and Hot Metal Tilting Device is the fundamental operation mode for optimizing converter-like processes.

### **Add-on module for Energy Recovery**

iRecovery® is the Energy Recovery technology developed by Tenova for steelmaking furnaces. In FMF case iRecovery® system is composed by a High Temperature and a Low Temperature section that recover thermal energy from the furnace off gases. The Energy recovery system is likely to be installed together with the FMF base module because of the energy intensive process of converter mode operation.

### **Add-on module for a substantial increase of the scrap in the charge mix**

In order to deal with a scrap percentage greater than 25÷30% the electrical equipment need to be implemented: transformer, secondary system, electrode arms and electrode regulation system; hydraulic system and auxiliaries have to be upgraded

Consteel® works as a scrap conveyor and preheating system, the more scrap percentage increases in the charging mix the more Consteel® comes back to its original function and well known advantages in term of efficiency and productivity.

## Add-on module robots

Robots are already helping or replacing operators in dangerous operation in order to improve the efficiency and safety of furnace environment. FMF can be integrated with the following robot add-on: TAT® Tenova Auto Tapping System, Temperature and sampling device robot, Slag door automatic cleaning robot and Electrode automatic charging robot.

## KT Injection System



The KT Injection System is ideally applied to Electric Arc Furnaces which operate in either electric and/or NO electric modes, considering the process, mechanical and maintenance aspects. Multi-point injection system that is another important feature of FMF base module and future add on as it allows aggressive decarburization on one side, but also control of homogeneity of the bath at the same time.

The main advantages of the KT System are summarized here below:

- ✓ OPTIMISED POSITION OF LANCES AND INJECTORS, respect to the level of the steel bath, which takes the highest efficiency of injection for oxygen and powder carbon.

Each furnace is individually engineered: for example KT Oxygen injector is studied on each furnace case by case on the basis of the expected results and the possible future improvements. The KT configuration takes into account future developments.

- ✓ MODULAR & PRACTICAL ENGINEERING, COMPACT DESIGN, EASY MAINTENANCE, LONG LIFETIME, which are all needs of a full reliable technology. TENOVA Engineering Department has developed a product to improve the process and to shorten the maintenance. KT injection system is designed to reduce the number of spare parts and to reduce and simplify maintenance operations.

The various items composing the KT system can be chosen and freely assembled to compose the needed injection tool. Every KT Lance is composed by three elements: a KT Copper Body (in oxygen-free copper, water-cooled), an injector (for oxygen, for carbon, for lime and other fines) and a specific back connector.

The KT injection system valve stands are equipped with on board Remote I/O boxes.

The valve stands are delivered tested in all their functionality. It permits to avoid installation of additional cable routes, as only one Ethernet line is needed to link this box with the existing net.

- ✓ SERVICE: All KT items are standardized, readily available in the TENOVA warehouse for prompt delivery to the customer. All KT items (bodies, connectors and injectors) can be shipped within two weeks from the order from the customer.
- ✓ HIGH FLEXIBILITY FOR KT PROCESS AND KT CONFIGURATION, it is possible to modify and optimize the process parameters through the KT Automation, on the basis of the raw material availability and steel production requirements.

It is possible to modify and adapt the KT configuration to suit charging needs for example to use it in the future as powder lime injection system, powder slag injection system, DRI fines injection system, etc.

- ✓ Possibility to INTERCHANGE PROCESS EXPERIENCES between all Customer's plants where KT lances are installed and interchange experiences and data with TENOVA KT After Sales Staff, which assures the process support and follow-up, even before the commissioning period.

In case of Customer's agreement, there is also the possibility of a process benchmarking, meetings and visits with other Steel plants using KT technology.

### **Hot Metal Tilting Device**



Hot Metal Tilting Device (HMTD) that allows to control the hot metal flow into the furnace in a continuous way bringing great process advantages. The hot metal tilting device (HMTD) is required to consistently feed hot metal into the furnace so the process control is optimized and stable. Additionally, the HMTD decouples the HM ladle handling from the furnace process, ensuring that minor crane issues have limited effect on the production.

The HMTD consists of:

- Fixed frame with hydraulic cylinders;
- Tilting frame with ladle supports;
- Weighing system;
- Protection shields.

### **FMF Base Module process example**

This is a description, simulated by Tenova, of a FMF operation without electric energy input to the process.

It is being considered an heat size of about 100 tIs and a metallic charge made of 85% hot metal plus 15% DRI/scrap

It is being assumed hot metal containing about 4% C, 0.55% Mn, 0.6% Si, 0.10 %P, fed into the furnace at a temperature of 1250°C via sidewall runner; DRI is fed from 5<sup>th</sup> hole through roof. In case of scrap, it will be fed via Consteel® conveyor.

The furnace will be tapped when the bath has reached a temperature of 1610°C, at a target chemical composition of about 0.070 % C, 0.02 % P.

The transformation process will also require a suitable charge of slag forming additives.

Considering the sensible heat provided by hot metal and the chemical energy developed by the massive oxidation of the charge the process is able to take place without electric energy supply and the chemical energy involved is so large that the addition of some coolant is necessary to maintain the bath temperature under control.

Similarly to BOF converters, scrap is the main coolant (even if preheated) but the cases, like the one at hand, in which scrap is not sufficient and some other coolant shall be considered; alternative cooling materials can be DRI, HBI, iron ore and limestone.

In this respect, the FMF can have an edge compared to a BOF converter since bath temperature and deslagging can be managed in a more continuous way (through the slag door), minimizing P reversal to the bath, without the delays introduced by a double slag practice.

When an FMF is equipped with scrap feeding by Consteel® system designed also for scrap preheating, the heat recovered by scrap can be used to extend the possibility to substitute more lime with limestone, enhancing the economic and the environmental benefits of this practice. (ref. [5]).

During the FMF processing of large amounts of hot metal, the feeding of slag forming materials is distributed along the continuous charging of the metallics (hot metal, scrap, DRI etc.) albeit the process starts with a batch large enough to cool down the residual slag from the previous heat (which contains most of the residual oxygen) reducing the initial reaction with the incoming hot metal.

Some hot heel is necessary in the FMF even when processing large amounts of hot metal, in order to be able to begin operating with the oxygen lances very soon, without excessive splashing and damages to the bottom hearth refractory. As soon as the initial bath reaction has calmed down, the feeding of hot metal is increased to bring down the bath temperature to the desired level (usually 1530-1560 °C) then the feeding of charge materials will be set to a lower value, following a profile designed to achieve a suitable bath temperature throughout the charging time.

In the FMF process case under consideration it is foreseen the use of three sidewall lances, each designed for the supersonic injection of 3200 Nm<sup>3</sup>/h of oxygen.

Lime injection may be considered to cool down specific areas of the refractory sidewall lining (e.g. near the entry of the hot metal).

FMF relevant performance indicators are reported in Fig.2. It has to be noted that when the FMF is operating with chemical energy only, like in the case at hand, the performance is more dependent on the characteristics of the charge materials than when electric energy is a major power source for the process, therefore a greater attention to the charge is a stronger precondition for the achievement of consistent results.

**Fig.2 FMF – Base Module – Performance Data**

<b>Charges</b>		<b>[total]</b>	<b>[/t/s]</b>
Metallic charge (* Including alloys into tapping ladle)	[kg]	114300	1143
Fluxes	[kg]	7500	75
Tapping size	[t]	100	
<b>Consumptions</b>		<b>[total]</b>	<b>[/t/s]</b>
Oxygen	[Nm <sup>3</sup> ]	5500	55
LPG gas	[Nm <sup>3</sup> ]	170	1.7

## Reference plants

FMF Base Module processes comparable to the one presented are already operating since years in a few Chinese reference plants, and a recent one at JSPL Raigarh (Fig 3).

**Fig.3 FMF - Base Module - References**

	Reference 1	Reference 2	Reference 3	Reference 4
Tapping size	100t	73t	60t	100t
Hot Metal %	86	90	90	87
Scrap %	14	10	10	
O2 Capacity	3 x 3800	3x3200 1x3000	2x3200 + 1x1000	4x3200
Average TTT	38 min	48 min	53 min	40 min
Yield	92%	92%	90%	88%
Year	2009	2013	2014	2015

## Economical comparison

Converter mode is the most challenging configuration for FMF, the following analysis shows an example of production data comparison between BOF and FMF Base Module (Ref [4]).

Production data refer to the FMF process example presented above and to a similar BOF process. The result shows that FMF process is an efficient process in term of productivity with high Hot Metal percentage in the charge mix.

**Fig.4 Typical productivity data for FMF and BOF**

	BOF	FMF
Charge Mix	80% HM 20% Scrap	86% HM 14% Scrap
Scrap charging	2 min	Continuous
Hot metal charging	5 min	Continuous
Oxygen blowing	17 min	31 min
Sampling and Analysis	3 min	During blowing
Tapping of steel	6 min	4 min
Deslagging	2 min	Continuous
Average service time	3 min	3 min
Average Tap to Tap time	38 min	40 min
Heats per day*	37	34
Tapping weight	100t	100 t
Heats per year*	12,500	11,500
Annual production*	1.250,000t	1,150,000t

\* Including average melt-shop delay

In terms of conversion costs, that is to say oxygen, electrical energy, refractory consumption, natural gas, nitrogen, argon, fluxes, FMF gets a figure of around 18 USD/tls, this value is absolutely comparable to BOF operations.

## **Conclusions**

The data collected in this study, together with the reference plants in operation and the ongoing projects draw a clear picture of opportunities and application for FMF. Full range of metallic charges can be smelted with capital costs reduced to the minimum level.

Flexibility is clearly the greater advantage of this solution for all the markets that are developing toward lower footprint steelmaking operations.

Data also show how FMF fits certain specific charge mixes becoming even more convenient than classical solutions.

In days to come, Tenova believes that FMF can be the first step for the modernization of Oxygen steel plants offering a smoother transition to the scrap era.

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