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ON DIRECT STEELMAKING FOR MINISECTOR USING AN INNOVATIVE PROCESS COMBINATION

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This paper highlights the possibilities of producing quality steels via DRI-SAF-ESR route. Techno-economic aspects of the process are also discussed briefly.

INTRODUCTION

In contrast with large integrated plants which employ oxygen steelmaking for refining the blast furnace hot metal, the minimills rely on electric arc furnaces for melting scrap and refining the liquid metal into steel. Further, minimills are gaining advantage in view of the continued dependence of the blast furnace route on expensive coke whose production (coke melting) is becoming environment unfriendly. One of the several dominating factors responsible for the increasing trend of mini-mills has been their ability to use direct reduced iron in place of steel scrap and equally significant is their versatality in terms of their products. Direct ironmaking which uses coal and ore directly, will eliminate the need for coking coals, coke making, agglemeration etc., thus resulting into lower capital costs and environmental problems.

Recent literature highlights the possibilities of innovative combinations of steps involving industrially proven technologies to produce steel economically and of acceptable quality. The guiding factors in such endeavors have been energy conservation and product value addition, both of which directly contribute to briging down the costs to such acceptable levels that the dream of small scale steelmaking can be realised in practice. Advanced melting processes and advanced near-net-casting processes offer potential techno-economic improvements in this regard as can be seen in the following sections.

In view of these developments, a process combination of DRI-SAF-ESR has been examined in some detail. The proposed technology route seeks to:

(a) reduce/minimise emissions causing environmental problems,
(b) reduce overall energy consumption in making steel,
(c) achieve value-addition through alloying, quality improvement and near-net shape castings,
(d) achieve cost-economy through lesser rejections as well as longer product service live,
(e) achieve economy of production on a small scale to meet the demands of the rural sector,
(f) achieve flexibility in the choice of input/feed materials (upto 100% sponge iron), and
(g) achieve versatility of products in terms of chemistry and shape based on regional demand.

The technologies in the proposed route are individually well-known, long-tested and commercially proven. The country possesses the capability to indigenously manufacture the equipment/machinery required for the processes in the proposed route.

On a laboratory scale, the National Metallurgical Laboratory, Jamshedpur, has the facilities for making sponge iron, liquid steel, and refined steel products through ESR.

Application of Electro Slag Refining and related technologies for processing metallised iron pellets/DRI/equivalent:

The processing of metallised iron pellets/sponge iron in equipment performing on the principle of electro slag remelting, has been receiving much attention lately. Electro Slag Remelting, widely known as ESR is a proven secondary refining technology commercialised throughout the world, both for ferrous and nonferrous metals as well as alloys. One of the interesting features of this enabling technology is its versatility and capability to produce shaped products.

The following major versions can be considered in the present context:

(a) ESR using cast/rolled solid consumable electrodes of sponge iron in water cooled moulds.

(b) ESR using isostatically pressed/compacted spongee consumable electrodes in water cooled moulds.

(c) ESR using non-consumable electrodes and direct charging of sponge iron in water cooled moulds.

(d) ESR using non-consumable electrodes and direct charging of sponge iron in refractory lined moulds.

In the above, versions (a), (b) (c) differ from (d) in respect of the solidification of the refined liquid metal. While in the former cases, in situ solidification takes place, in the latter case the refined liquid metal can be cast to any shape separately within certain dimensional limits. The equipment used in (d) is referred to as electro slag crucible furnace (ESCF) and the refined liquid metal after alloying, if required, can be cast in a centrifugal casting machine or a static casting unit using metal moulds of required contours. Besides, due to high conservation of thermal energy as a result of the absence of water cooled metal moulds in (d) as compared to (a), (b) and (c) the electrical energy requirement is almost half in the case of (d) as compared to the cases (a, b and c). The process under (d) is some times referred to as Electro Slag Resistance Heating or simply Electro Slag Heating.

The method of producing steel from spongee iron/pre-reduced pellets can vary significantly, depending on the type of electrodes used (consumable or non-consumable), the type of container used (water cooled moulds or refractory lined crucible), the number of technological conversion stages (single or two stage) and the state of the product (liquid metal or metal solidified by water cooling). The relevant information relating to the processing of spongee iron-type materials in ESR and ESR based processes is well documented in literature [1-8].

The energy advantages of the Electro Slag Crucible furnace

It is encouraging to note from the reported literature, that many successful attempts have been made the world over to process sponge iron in electro-slag melting equipment of one kind or the other. There is no doubt that major improvements were made in the processing of sponge iron in conventional UHP electric arc furnaces, particularly with respect to the life of the furnace lining, working with shorter arc, utilisation of water cooled side panels instead of fire-proof top, etc. However, the EAF can not be considered to be optimum choice due to the type of energy transfer and its processing concepts, environmental problems etc. Also limiting the use of EAF in spongee iron processing is the presence of slag components like iron oxide and gangue. It has been reported that spongee iron with low degree of metallization and/or high percentage of gangue content can not be economically processed in EAF. On the other hand, electro-slag processes, such as Electro Slag Crucible melting, Electro Schlacke Winderstand (ESW), Electro Slag Heating, emphatically suggest that spongee iron of lower metallization and higher gangue content also can be easily processed in these systems. As an example, Table I gives the change of composition of the spongee iron resulting from different grades of iron ores at a metallization degree of 90%. Table II shows the amount of lime addition and slag volume in kg/t of liquid steel, and energy consumption in kwh/t of liquid steel for the processing of 100% spongee iron from ores of various grades at 90% metallization using (a) EAF, (b) ESW and (c) Duplex ESW-Arc Processes.

The above resuls clearly indicate that the ESW furnace (or Elecro Slag Crucible Furnace) has a lower energy consumtion, and the ability to process spongee iron of larger gangue contents as compared to the EAF. Particularly noteworthy is the moderate energy consumption of 600 ± 50 kwh/t of steel in the case of Duplex ESW-Arc Process.

In the same spirit, the two stage process developed at the Metallurgy Research Centre in Albany (Oregon, USA) uses the combination of arc smelting of spongee iron with a graphite electrode and separation from the pellets of acid gangue, with subsequent electro-slag casting (ESC) into shaped ingots. However, the use of EAF prior to ESC can be modified with the electroslag crucible furnace (ESCF of ESW or ES-Heating) for obvious advantages. A schematic of such a modification alongwith the possible energy conservation and value addition can be visualised in Figure 1.

In a typical case using the combination of hot DRI-ESCF followed by processing the liquid steel in ESC and finally producing ESR quality alloy steel shaped products like tubes, rings and slabs of high aspect ratio (width/thickenss), less than 1200 kwh/t will be required (excluding for sponge iorn) with a relatively lower capital cost and less environmental problems. This, combined with the flexibility in the input materials and versatility in the products extending into various steel grades to shapes based on particular demand, difinitely deserves a serious attempt in our country. Other combinations include ESCM + EAF followed by slab casting/shape casting; ESCM in conjuction with centrifugal casting or static casting in metal moulds to produce a variety of automobile and other cutter and tool components; or partly normal steel through ESCM and partly quality steel by any of the above mentioned combinations. In all these, energy savings and product value addition can be expected to off-set the cost of steel production even on a moderate scale.

WORK PLAN

1. Development of a comprehensive data base on the performance indices of the existing DRI/EAF minimills in the country with special reference to environmental and energy aspects.

2. Revamping of the DRI/SAF/ESR facilities existing at NML for processing spongee iron i nto steel.

3. Trial runs/experiments using the revamped facilities and carrying out monitoring of emissions and energy consumption.

4. Analysis of the data generated in Activity 3 and an objective assessment of the techno-viability of the proposed route.

5. Documentation inclusive of a recommended work-plan for a large scale operation.

CONCLUSION

From a thorough analysis of the developments taking place the world over, the prospects of finding a suitable process or a combination of processes which are well established and commercially proven to produce steel from sponge iron look very promising. Conserving the thermal energy through hot charging of sponge iron and hot liquid steel into the respective melting/refining units on one hand, and alloying, refining and shape casting into value added products on the other, will undoubtedly bring down the cost of mini steel making to acceptable levels. Producing near-net shape casings, such as gear blanks, T-joints, automotive parts, several types of cutters, sprockets, pulleys, couplings, rings, wheel blanks, forks, connecting rods etc., using electro slag crucible melting followed by centrifugal casting with low capital costs and less energy consumption can surely be a techno-economic boon for the small scale steel making and can possibly be considered for the rural sector.

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Table I Composition of sponge iron produced from various grades of iron ores (Fe_2O_3 type) at 90% metallization [6]								
Iron Ore, %								
Fe dry	68.00	66.00	64.00	62.00	60.00	58.00	56.00	54.00
Fe metal	61.20	59.40	57.60	55.80	54.00	52.20	50.40	48.60
O_2(FeO)	1.95	1.89	1.83	1.78	1.72	1.66	1.60	1.55
C	1.46	1.42	1.38	1.33	1.29	1.25	1.20	1.16
Ganart (Gangue)	2.76	5.62	8.48	11.34	14.20	17.06	19.92	22.78
Total	74.17	74.93	75.69	76.45	77.21	77.97	78.72	78.49
Sponge Iron								
Fe total	91.68	88.08	84.56	81.10	77.21	74.39	71.14	67.93
O_2	2.63	2.52	2.42	2.33	2.23	2.13	2.03	1.95
C	1.97	1.90	1.82	1.74	1.67	1.60	1.52	1.46
SiO_2	2.60	5.25	7.84	10.38	12.87	15.31	17.72	2.06
CaO	0.37	0.75	1.12	1.48	1.84	2.19	2.53	2.87
AI_2O_3+MgO	0.75	1.50	2.24	2.97	3.68	4.38	5.06	5.73
Total	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table II. Lime addition, slag volume and energy consumption for the processing of 100% sponge Iron from ores of various grades (Fe_2O_3 type) at 90 % metallization for EAF,ESW and Duplex ESW- EAF								
Ore grade (% Fe)	68.0	66.0	64.0	62.0	60.0	58.0	56.0	54.0
(a) Electric arc process								
slag kg/t	125	265	419	588	774	981	1212	1459
lime,kg/t	45	95	150	210	277	351	434	526
power,kwh/t	553	609	671	739	813	896	989	1092
(b) ESW Process								
slag kg/t	92	195	307	429	562	708	890	1049
lime,kg/t	22	47	75	104	136	172	211	254
power,kwh/t	506	542	581	624	670	721	778	840
(c) Duplex ESW arc process								
slag,kg/t	110	166	226	291	361	437	519	609
lime,kg/t	40	40	40	40	40	40	40	40
power,kwh/t	550	564	579	595	613	632	653	675

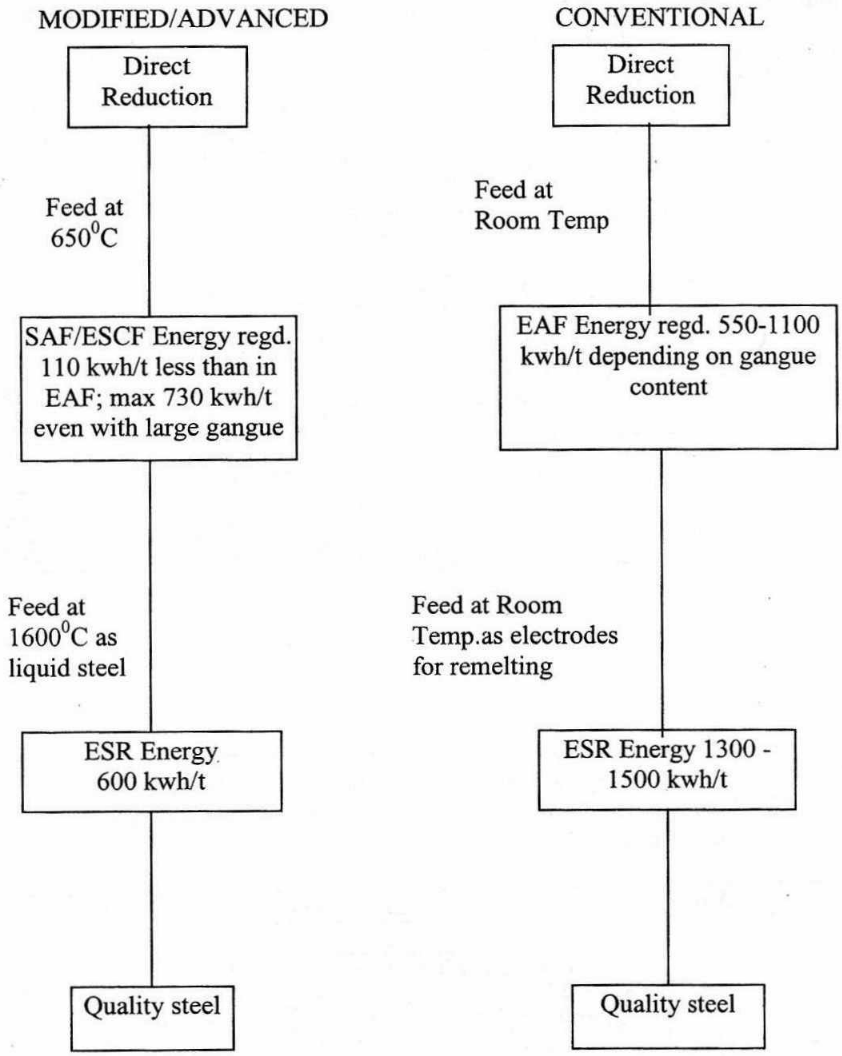

Fig. 1 Direct steel making technologies