Vol. LVI, No. 2, June 2023

IRMA JOURNAL **-** A Publication of:
INDIAN REFRACTORY MAKERS ASSOCIATION
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REAL®, THE BEST ALUMINAS FOR HIGH-PERFORMANCE REFRACTORIES

MESSAGE FROM THE CHAIRMAN

Dear Colleagues,

I have always believed in "India Story" and it won't be any gainsaying to state that success of the story is being gradually realized worldwide. As the global economy slugs, India along with few other nations offer growth sweet spots. The International Monetary Fund (IMF) expects India to grow by 5.9% in FY 2023–24 and by an average rate of 6.1% over the next five years. We need some more administrative reforms, some direct Government engagements to remove the bottlenecks in capital investment by private sector. While service sector continues its bull run especially in the export sector, manufacturing too is gradually making its presence felt. India has all the potentials to become global manufacturing hubs of many a products, and refractories is certainly one of them.

We have to accept the fact that digital transformation is the future, sustainability is the key and leaving a clean green world is our collective responsibility. This is a big paradigm shift from mere production, selling and invoicing. In the recently concluded IREFCON22, we had an exciting discussion Industry 4.0 and how it is going to shape the future of the refractory industry.

Coming back to the main issue, with 17% of the nation's GDP and over 27.3 million workers, the manufacturing sector plays a significant role in the Indian economy. Through the implementation of different programmes and policies, the Indian government hopes to have 25% of the economy's output come from manufacturing by 2025. In this context, can we expect the manufacturing pie to grow without seamless support from the refractory industry? The answer is resounding NO. Along with India Story, Indian Refractory Industry's Story is on the anvil, provided we act in a diligent way. Trust me, you will always find your Association by your side in your exciting growth journey.

Ish Garg
Chairman

ASSOCIATION ACTIVITIES

IRMA Board of Directors Meeting

IRMA Board of Directors meeting was held on 22nd April 2023 on Zoom platform. The issues discussed were plans for IREFCON24, review of market conditions etc.

Paper on Secondary Steel Sector.

IRMA has prepared a White Paper on proper usage of refractories in secondary steel sector as per the suggestion of Ministry of Steel. The paper contains theoretical framework for selection of refractories as well as practical outline of the solutions to the possible problems faced by the steel makers in secondary sector.

IN THE NEWS

Refractories in PLI 2.0

The Centre is looking to include refractories in the upcoming Production Linked Incentive Scheme 2.0 for steel as it aims at doubling the country's production capacity for the metal to 300 million tonne by 2030. Ministry of Steel is currently in talks with the refractory industry to develop an incentive policy to boost domestic production and reduce the country's dependence on imports from China.

Tata Steel

Tata Steel, is planning a consolidated capital expenditure (capex) of Rs 16,000 crore for its domestic and global operations during the current financial year, reported PTI. Of this, Rs 10,000 crore has been earmarked towards Tata Steel Standalone operations of which the Kalinganagar project will account for approximately 70 per cent. The company is in process of expanding capacity of its plant at Kalinganagar, in Odisha to 8 MT from 3 MT.

New Steel Capacity

As per ASSOCHAM, around 40 million tonne (MT) of new steel-making capacity will be commissioned by 2025-26. Domestic steel production capacity is expected to touch 300 MT and crude steel production is likely to reach 255 MT by FY31.

AMNS India

AMNS India, will invest $7.4bn in capacity expansion and increased value-added capabilities. The investment includes increasing the Hazira-based plant's upstream capacity to 15 million tonnes by 2026, alongside increased downstream facilities costing $1bn to meet rising demand from automobiles.

India's Crude Steel Production

India's crude steel production rose by 4.18 per cent to 125.32 million tonnes (MT) in 2022-23, according to research firm SteelMint. In the preceding 2021-22 fiscal, the country produced 120.29 MT of steel, the research firm stated. As per ICRA, India's crude steel production capacity utilization will be around 80% for the year 2023-24.

Domestic Coal Supply

Minister for Coal and Mines, Pralhad Joshi has informed that there is no shortage of coal in the country and there will be no need to import thermal coal from fiscal 2024-25. He also said that India aims to bid out 500 mineral blocks by 2025-26.

Appointment

Mr Amarendu Prakash has taken over as Chairman, Steel Authority of India Limited (SAIL). Prior to this, Mr Prakash was Director in-charge at Bokaro Steel Plant (BSL), a post he held since 2020. He is a metallurgical engineer from BIT Sindhri and joined SAIL in 1991 as a Management Trainee (Technical).

OVERSEAS NEWS

HarbisonWalker International

HarbisonWalker International (HWI), which announced in February 2023 that it would combine with Calderys, has unveiled a new brand identity. The new look reflects HWI as a member of Calderys, the global refractories company's brand in the Americas.

INTOCAST AG

INTOCAST AG has acquired EXUS Refractories S.p.A, based in Avezzano, Italy. The completion of the transaction is still subject to obtaining the authorizations required by applicable law. The acquisition represents another important step in the corporate group's global expansion strategy and strengthens its position as a full-range supplier provider of refractory products.

RHI Magnesita

RHI Magnesita has published an update on trading for the three months to 31 March 2023 ('Q1'). Refractory sales volumes in the first quarter were 8% lower than Q1 2022, in line with management expectations and overall market demand. Steel and cement demand outside of India and China had softened due to a slowdown in construction activity, whilst demand in the Industrial Projects segment remained strong. The Group was able to reduce gearing due to strong operating cash flows and through the proceeds of the QIP, whilst continuing to execute on its inorganic growth strategy. Total investments in M&A of €155 million were completed during Q1 2023, including the acquisitions of the Indian refractory business of Dalmia Bharat Refractories Limited and Hi-Tech Chemicals Limited, and a €5 million investment in MCi Carbon, Australia. The acquisitions of Dalmia OCL and Hi-Tech completed in India during Q1 increased the Group's local market share from around 20% to 30%.

Syrah Resources

Gross profit of Syrah Resources for the 2022 was $13 million and net loss after income tax of $27 million for the full year. The company had record annual graphite production of 163kt from Balama, Madagascar. The company updated its reserve estimate stating that Balma supports a 50+ year mine life based on its current 2 Mtpa process plant capacity with a life of mine average strip ratio (waste/ore) of 0.5 and ~19% TGC ore grade processed to 2047.

Global Crude Steel Production Figures

In 2022, 1885 million tonnes of crude steel was produced globally. China tops the list with 1018 million tonnes, followed by India at million tonnes and Japan at 89.2 million tonnes. USA stood 4th with 80.5 million tonnes and Russia 5th at 71.5 million tonnes.

Global Alumina Production

According to statistics released by the International Aluminum Institute (IAI), global alumina production totaled around 33.18 million tons in the first quarter of this year, sliding by 5.5% compared to the preceding quarter and by 1.14% from the year-ago level.

Elkem S.A

Elkem ASA has acquired VUM, a Slovak producer of carbon materials. The transaction will further increase Elkem's capacity and competence in specialty markets and increase its flexibility in the supply chain. Elkem expects the acquisition to contribute with an additional turnover of around NOK 360 million per year.

MEMBERSCAN

Sarvesh Refractories

Sarvesh Refractories has been chosen as the recipient of the "Top Sellers on GeM - MSE Category" in the "Kreta Vikreta Gourav Samman Samaroh 2023" awarded by the Government e-Marketplace (GeM).

TRL Krosaki Refractories

TRL Krosaki has achieved the highest ever casting duration by TRLK Tundish of 18 Hours 11 Minutes (Guaranteed life- 14 Hours) at SAIL RSP SMS#2 CC#3. In this tundish TRL Krosaki has used BPH Made Mono Block Stopper and BPH Made Upper Tundish Nozzle which support to make the benchmark of highest utilization duration of 18 Hours 11 Minutes by TRLK Tundish. TRL Krosaki has also utilized BPH Made Ladle Shroud.

Vesuvius India

Vesuvius India has won the Gold and Silver positions of prestigious World Refractories Association Safety Awards. Vesuvius Costumer Location - SAIL Bhilai won the Gold Award while Vesuvius India Ltd – Kolkata plant won the Silver Award.

ECONOMY AT A GLANCE

- Globally, the baseline forecast is for growth to fall from 3.4 percent in 2022 to 2.8 percent in 2023, before settling at 3.0 percent in 2024. Advanced economies are expected to see an especially pronounced growth slowdown, from 2.7 percent in 2022 to 1.3 percent in 2023. In a plausible alternative scenario with further financial sector stress, global growth declines to about 2.5 percent in 2023 with advanced economy growth falling below 1 percent. Global headline inflation in the baseline is set to fall from 8.7 percent in 2022 to 7.0 percent in 2023 on the back of lower commodity prices but underlying (core) inflation is likely to decline more slowly. Inflation's return to target is unlikely before 2025 in most cases.

- Growth in developing Asia is forecast at 4.8% this year and in 2024, up from 4.2% last year. The People's Republic of China's (PRC) recovery and healthy domestic demand in India will be the region's main growth supports this year and next. An array of immediate and emerging challenges could still hold back the region's recovery. Policy makers should stay vigilant in the post-pandemic environment of higher inflation, interest rates, and debt. Governments must continue supporting multilateralism, and lean against the risks of global fracturing.

- Goldman Sachs has raised India's GDP growth forecast for calendar year 2023 by 30 basis points to 6.3%, citing a rise in exports. The earlier forecast was made in November, which showed that Indian economy will grow at 5.9%.

- Inflation has shown notable signs of receding thanks to continued efforts by the Reserve Bank of India (RBI). India's retail inflation, which is measured by the consumer price index (CPI), slipped to an 18-month low of 4.70% in April 2023 and the wholesale price index (WPI) declined to -0.92% in April 2023, from 1.34% in March 2023.

- A recent FICCI Manufacturing Survey showed nine out of twelve sectors operating at above 70 per cent capacity in Q4 of FY23. The outlook for Q1 FY24 in the sector, as assessed by the RBI's Business Expectations Index (BEI), moderated from the previous quarter on account of seasonal factors but notably remains above its historical average.

- The production growth of India's eight key infrastructure sectors slowed down to a six-month low of 3.5 per cent in April 2023 because of a decline in the output of crude oil, natural gas, refinery products, and electricity. In April last year, the core sector growth recorded 9.5 per cent, while in March 2023 the key infra sectors clocked a growth rate of 3.6 per cent.

BUSINESS SECTION:

ENERGY MAPPING OF BANGABHUMI REFRACTORY CLUSTER: A SAMEEKSHA DOCUMENT

(Original work of TERI done under the project "INDIA: TERI-SDC Partnership: Scaling up Energy Efficient Technologies in Small Enterprises (EESE)

Overview of cluster

Asansol refractory cluster is the one of the important industrial clusters in West Bengal. The Asansol-Burnpur area is located in the land area between the river Ajoy on northern side and river Damodar on the southern side. The area is located within the Raniganj- Asansol coal mine belt. It is rich in mineral resources such as coal, lime stone, fireclay, china clay, granite, stone and sand. The refractory cluster under this region is developed within 50 kilometer around Asansol town. Some of the large industries located in and around the cluster are Durgapur Steel

Asansol refractory industries
Source: Google maps

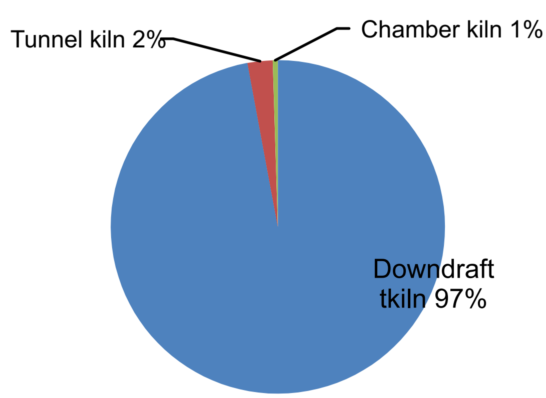
Plant, Alloy Steel Plant, Hindustan Cables Ltd., Burn Standard Co., Eastern Coalfields, Chittaranjan Locomotives, Maithan Steel & Power Limited, Damodar Valley Corporation etc.

Apart from these, there are also a few large ceramics (Maithan ceramic limited, Associated ceramic limited, foundries (cupola based and induction furnace based units), sponge iron units and coke oven industries. The industries in the cluster under micro, small and artisan categories include engineering & fabrication, refractories, mineral, leather, paper products, rubber goods, etc. The refractory cluster is more than 100 years old. The refractory materials produced are used within the country. The primary domestic market includes large steel manufacturing industries within 200 kilometre area like TISCO (Digwadih), TELCO (Jamshedpur), IISCO (Jamadoba), Bokaro Steel, SAIL (Durgapur), Alloy steel plant – Durgapur, etc. A small quantity is also exported to neighbouring countries.

Product types and production capacities

There are about 206 refractory industries in the cluster of which about 200 units use downdraft (DD) kilns. Five (5) units are tunnel kiln based and one unit is equipped withchamber kiln. The industries are located in about 50 kilometre radius. Some of the primary areas are Gorandi, Salanpur, Burnpur, Chittaranjan, Kulti, Raniganj, Jamuria, Hirapur, Kalyanpur and Asansol etc.

The type of refractory products manufactured in the cluster include different categories of refractory blocks and bricks, graphite stopper head, insulation bricks, ladle, refractory mortar, ramming mass, roof bricks, silminite bricks, suspended roof bricks, monolithic, burner quarl, bottom pouring, silica brick, etc.



Distribution of Kilns

The average production capacity of DD kilns is about 100 tonne per month (tpm) with 20 feet size whereas of tunnel kiln is 600 tpm (20 tonne per day). The chamber kiln produces around 750 tpm (25 tonne per day). The total production of different refractories in the cluster is estimated to be 1,20,600 tonne per year (tpy), which is around 42% of the installed capacity. The average level of rejections from DD kilns is reported to be about 10%.

Energy scenario in the cluster

The refractory units located in different industrial areas of Asansol cluster use coal as the major fuel in both downdraft and chamber kilns. The tunnel kilns use petcoke for firing. Electricity is used for all motive power requirements. The sources of grid power include Dishergarh Power Supply and Damodar Valley Corporation. DG sets are used during power failure. The details of major energy sources and existing tariffs are shown in the table.

Prices of major energy sources

Energy source	Price
Coal	Rs 8,500 per tonne
Petcoke	Rs 15,000 per tonne
Diesel	Rs 60 per litre
Electricity	Rs 5.50 per kWh

Production process

Manufacturing of refractory item uses wide range of raw material combination to produce different customized shape, size and unshaped refractory mass. It requires both electrical as well thermal energy at different stage of the process through connected process equipment and plant utilities like motors, pumps, different presses, kilns etc. Refractory manufacturing process primarily consists of die/mould preparation, crushing, grinding, mixing, shaping (pressing/casting), drying and firing. The different steps of manufacturing steps are described below.

(i) Mould preparation

Most of the products are shaped using dies, which are normally outsourced and kept ready in stock for use the production. The castable refractory products are made using customized pre-fabricated in-house moulds as per requirements of product dimensions. Dies and moulds are designed as per the product dimensions required by potential customers.

(ii) Raw material preparation

The refractory units procure basic raw materials such as plastic clay and other ingredients as lumps or powder which are generally tested in laboratories to match customer requirements. Jaw crushers are used to reduce the size of lumps before they are sent for grinding.

(iii) Grinding and screening

Grinding is a batch process for reducing the size of batch materials. It ensures homogeneity of the material being processed. Ball mills are used for grinding process. In ball mills, the raw materials are grinded to reduce size as per requirements for pressing. Screening is done to separate large particles present if any, from batch material to avoid any potential imperfection in products.

(iv) Mixing

Mixing of raw materials is done in Muller machines. It is done in batches of fixed quantity. These machines are used for uniform and quick mixing of a heterogeneous mass of two or more materials of varying aggregate size mechanically into uniformly blended batch of raw materials. Mullers are fitted with large mulling rollers for mixing of raw materials. Water is added to raw materials in required proportions and loaded in muller machines to obtain homogeneous mass of raw material.

(v) Pressing

Pressing machines are used to provide shape to the product. Each refractory unit has 4 to 6 press machines which are operated manually. Two types of press machines are commonly used in the cluster namely (1) Hydraulic press of 30-150 tonne capacity and (2) Friction press of 80-200 tonne capacity. The type of press used is dependent on type of products being manufactured. For large size products, friction press is commonly used; hydraulic press is used for other products. The homogenously mixed raw material in Muller machine is loaded manually in hydraulic/ friction press to provide shape and strength to the products. The pressed product is manually removed for drying.

Friction press

Hydraulic press

(vi) Drying

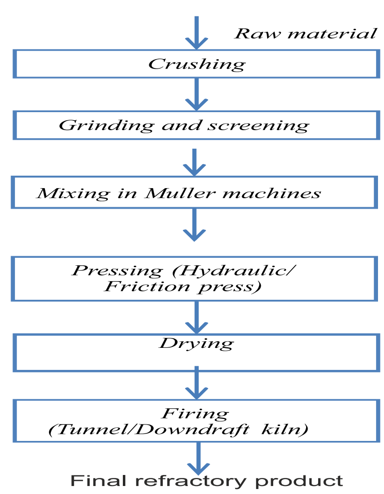
The green products are stacked inside sheds to allow slow and uniform drying in DD kiln based units. The dried products are manually loaded in downdraft kilns for further firing. Tunnel kilns are equipped with dryers which utilize waste heat available in flue gases for removal of moisture from moulded products.

Natural drying of green refractories

(vii) Firing

Firing is the process by which refractories are thermally consolidated into a dense, cohesive body composed of fine and uniform grains. This process also is referred to as sintering or densification. Refractories are generally fired at 50-75% of the absolute melting temperature of the body material. Downdraft kilns are commonly used by the refractory units in the cluster and a few units are using tunnel kilns for firing process. The final temperature depends on the material composition used in products (hollow/solid), size and stacking (only solid/ only hollow/ mix of hollow and solid products). Generally, fire temperature is 1150^{0}–1200^{0}C and some special product may need to be fired at more than 1400^{0}C.

A typical manufacturing process followed in the cluster for production of refractory products is shown in the figure.



Process flow chart for refractory manufacturing

Technologies employed

(i) Downdraft kiln

Traditionally, Asansol refractory industries are using downdraft kilns for firing of refractory products. DD kilns are batch type systems, wherein loading and unloading of refractory products and firing is carried out manually. Coal is the fuel used in downdraft kilns. The traditionally designed DD kilns in the cluster have the followings feature in common.

- Design specifications of DD kiln, lining material and flue path layout are old and do not have proper design.
- Coal is not properly sized before feeding into coal grate. It is also loaded at irregular intervals and varying quantities.
- Layout of existing coal grate and its capacity are unscientific thereby permitting flame/ flue to travel fast without proper heat transfer to refractory blocks
- Dampers are very provisional arrangement without proper maneuvering lever in place resulting in high negative drafts
- Measurements of furnace temperature are not being done barring a few units which use pyrometer for measuring furnace temperatures
- There is no control of combustion air through coal grate which is always open. This provides no option for throttling to reduce airflow if felt necessary during firing cycle.
- Long flame carry over to chimney base was observed indicating high flue velocity and low residence time resulting in higher level of coal consumption
- High surface temperature at loading/ unloading area, which needs to be appropriately insulated with movable fixture for repeated use

Most of the DD kiln units have two kilns with different size to cater variable production volume in a given season. The internal diameter of the kiln may vary within 16–26 feet (4.88-6.70 metre) with the average size being 20 feet (6.1 metre). However, flue path size and length depends on the individual site layout and chimney location, which is unscientific. Cycle time per batch production depends upon kiln size, quantity of refractory stacked, product mix in the stack and type of material under firing. The total cycle that includes stacking of green refractory, firing, cooling and unloading is about 20 days.

(Ii) Tunnel kiln

Tunnel kilns are continuous type and can be operated using pet coke, oil and gas. There are about 5 number of tunnel kilns operating in the cluster. Of these, smaller tunnel kilns use 3 cars with 2 tonne capacity per hour and large tunnel kilns uses more numbers of cars per hour with similar capacity and operated continuously for short duration depending on market demands. Mostly large plants with 5 cars are operated regularly at full production capacity.

Tunnel kiln

The tunnel kilns in the cluster use pet coke as the fuel. The refractory products loaded in trolleys, after removal of moisture in the dryer, are pushed inside the tunnel kilns using an adjustable mechanical pusher mechanism. As the trolleys move inside the tunnel kiln, the products are gradually preheated close to about 700-800 °C before reaching firing zone. Pulverized pet coke is used as fuel in the cluster and is fed through an automatic fuel feeding system. The temperature of the firing zone is close to 1300°C wherein the products are soaked to about 1½-2 hours. The quantity of fuel is controlled through a feedback loop system with the temperature of firing zone. The products are gradually cooled down after the firing zone to about 50-60°C before they exit the kiln.

(iii) Chamber kiln

A chamber kiln consists of number of rooms or chambers with permanent side wall and roof that are arranged in series with provision of coal grate for firing stacked refractory products for vitrification. Each chamber is connected to the next chamber and with the central chimney in a manner that would help in directing flue gas from source to chimney after it travels through next chamber by appropriately positioning damper in flue path and passageway in partition wall. During firing cycle, hot exhaust gases from room under fire will be directed through passageway

Chamber kiln

provided in partition wall to following adjacent two rooms in series that are scheduled to be fired next. While hot gases pass through the kiln circuit, they transfer heat to the stacked refractories thereby preheating stack materials. Finally, flue gases at reduced temperatures will be dispersed through the chimney. This arrangement recovers sensible heat of hot exhaust gases thereby making chamber kilns more efficient than downdraft kilns.

Chamber kilns are also batch type kilns, wherein loading and unloading of refractory products and firing is carried out manually. Coal is the primary fuel used in chamber kilns. The key features of chamber kilns used in the cluster are as follows.

- Design specifications of the kiln, lining material and flue path construction require improvements. The kilns do not use compatible refractory material.
- Coal is not properly sized before feeding into coal grate. It is also loaded at irregular intervals and varying quantities leading to significant unburnt losses.
- Manual control is practiced across the cluster for monitoring and control of furnace temperatures
- Limited use of ceramic blanket and insulating refractory in furnace construction.

Kilns used in Asansol refractory cluster

Type of kiln	Numberof kilns
Downdraft kiln	200
Tunnel kiln	5
Chamber kiln	1
Total	**206**

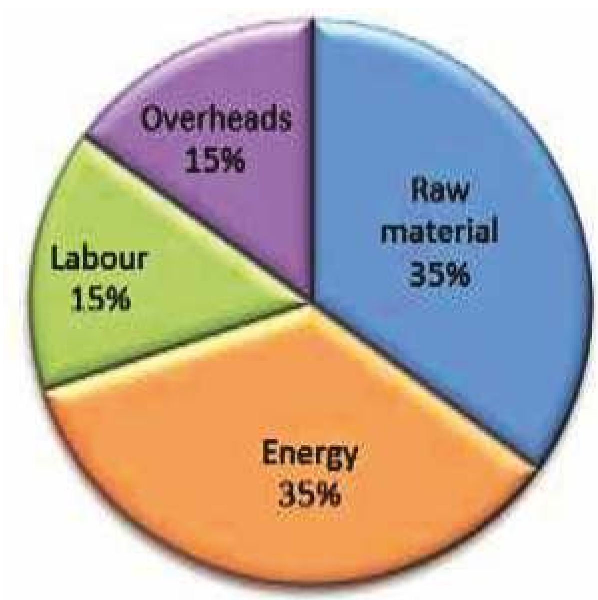
Energy consumption

Coal is the main fuel used in downdraft and chamber kilns and petcoke is commonly used in tunnel kilns for firing of refractory products. Electrically operated plant utilities such as press, crusher, muller, vibrating screen and belt conveyor are operated using power supply from local grid. Normally power cut from grid does not interrupt firing cycle except tunnel kiln, which requires standby power source (generally DG set) to continue operation. The energy consumption in different kilns is also dependant on type of products and the firing temperature needed. The temperature requirements of different refractory products are in the range of 1280°C–1310°C.

Fuels used in kilns

Type of kiln	Fuel used
Downdraft kiln	Coal
Chamber kiln	Coal
Tunnel kiln	Pet coke

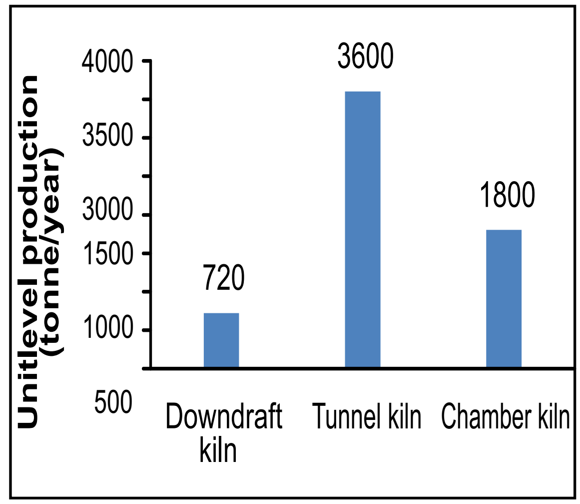
The share of production cost for regular refractory products is same for energy as well as raw materials, which is about 35%. The raw material cost for better quality high end products may go up to 50% of total production cost.



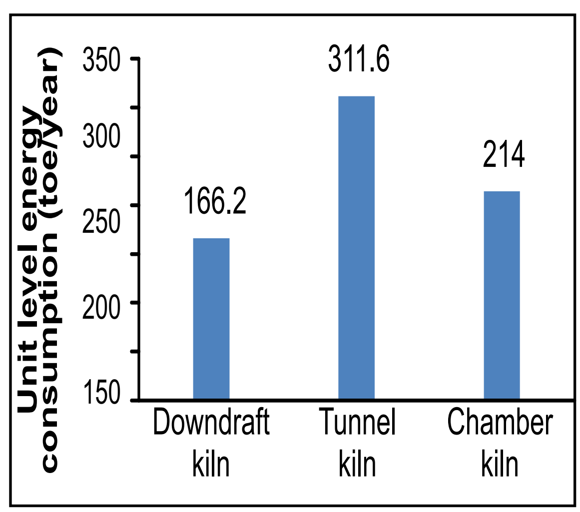
Share of production cost

(i) Unit level consumption

Thermal energy (coal/petcoke) accounts for about 98% of share in total energy consumption in a refractory manufacturing industry. Product forming/ moulding is done through electrical presses but operated manually. However, the share of electrical energy consumption is negligible as compared to the energy consumption required for firing process.



The total energy consumption of the refractory unit in the cluster varies from 166 toe per year (downdraft kiln) to 312 toe per year (tunnel kiln) as shown in the figure. The unit level energy consumption depends on "specific energy consumption" (SEC) of the kiln and the annual production. The production in DD kiln is quite low whereas it has very high SEC level.



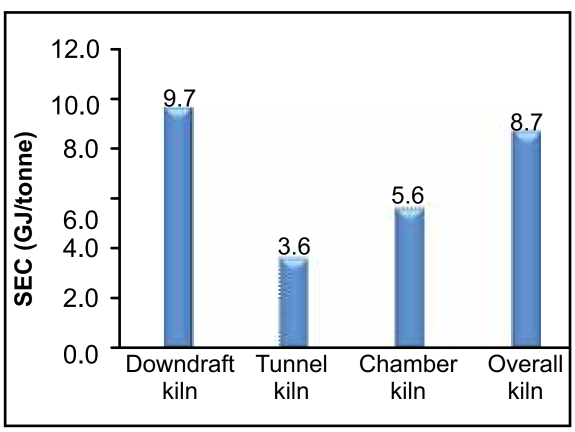
The typical energy consumption by refractory industries using different technologies in Asansol cluster is shown in table.

Typical energy consumption of kilns

Unit level energy consumption

Type of unit	Thermal energy (tpy)	Diesel (L/ yr)	Electricity (MWh/ yr)	Total energy (toe/yr/unit)
Down draft kiln	252 tonne coal	240	25.2	166
Chamber kiln	360 tonne coal	600	60.0	214
Tunnel kiln	360 tonne petcoke	1200	180.0	312

With the batch type process, the SEC of downdraft kiln units is about 9.7 GJ per tonne of refractory product whereas, the SEC of tunnel kilns of continuous type is about 3.6 GJ per tonne and of chamber kiln is 5.6 GJ. The weighted average SEC of refractory units at cluster level is about 8.7 GJ per tonne as shown in the figure. Higher SEC levels of DD kiln units may be attributed to a larger dead weight used (support structure) as well as high heat losses in flue gases. The typical SEC of different kilns in the cluster are provided in the able.



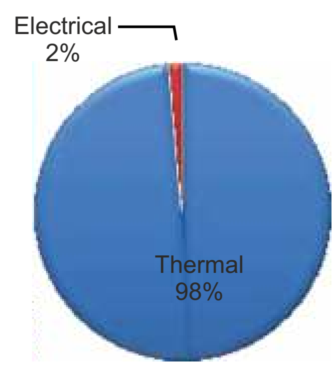
SEC variations at cluster level

Specific energy consumption of kilns

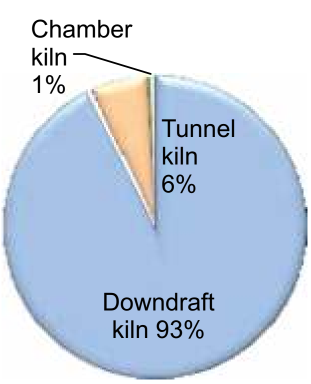
Kiln type	Specific energy consumption	
	kcal/kg	GJ/ t
Downdraft kiln	2308	9.7
Chamber kiln	1339	5.6
Tunnel kiln	866	3.6
Overall	**2078**	**8.7**

(ii) Cluster level consumption

The total energy consumption at cluster level is estimated to be 25,063 toe per year. The share of energy consumption by thermal energy (coal, petcoke and diesel) is about 98% and of electrical energy is 2% (figure). It may be noted that coal is consumed only by chamber and DD kilns, whereas petcoke by tunnel kilns. The consumption of diesel towards meeting electricity consumption during power failure is negligible. The GHG emissions at cluster are estimated to be 105,295 tonne of CO_2.



Consumption share of energy form at cluster



Share of energy consumption by kilns

The break-up energy consumption and the corresponding energy bills and GHG emissions of different energy sources are provided in the table.

Annual energy consumption of Asansol refractory industry cluster

Energy type	Annual consumption	Equivalent energy (toe/ yr)	GHG emissions (t CO_2/ yr)	Annual energybill (millionINR)
Coal	35640 tonne	23,166	93,555	303
Petcoke	1800 tonne	1,476	7,230	27
Electricity	4.49 million kWh	386	4,403	24
Diesel	40.2 kilo litre	35	107	2
Total		25,063	105295	356

Energy saving opportunities and potential

Asansol refractory cluster offers significant scope for energy savings from adopting best practices to energy efficient technologies. Some of the major energy saving opportunities in Asansol refractory cluster are discussed below.

(i) Downdraft kilns

Use of insulating refractory in lining

Traditionally, the linings of downdraft kilns are made mainly with low grade refractory bricks. Higher thickness of refractory inside walls and crown has led to considerable reduction in surface temperatures but have led to increased dead-mass resulting in higher heat losses during each firing cycle. It is suggested to modify existing lining with insulating refractories which would reduce heat losses through kiln surfaces. Further, ceramic fibre blankets can be added between layers of bricks in bottom layer, side wall and the crown that would help in reducing heat losses.

Sizing of coal and feeding practices

Coal is the primary energy source in downdraft kilns. It was observed that (1) large quantity of coal is fed every time without considering inside furnace temperatures and (2) coal lumps are fed and no proper sizing of coal is maintained. This leads to insufficient opening for combustion air supply resulting in thick black smoke from chimney exhaust. Thus improper fuel size and feeding practices have affected the thermal performance of DD kilns in the cluster. It is suggested to (1) use coal of about to 1 inch size before feeding and (2) maintain suitable fuel feeding frequency based on requirements of the kiln which would ensure improved and complete combustion of fuel and avoid formation of black smoke from chimney.

Installing temperature indicators for monitoring furnace temperature

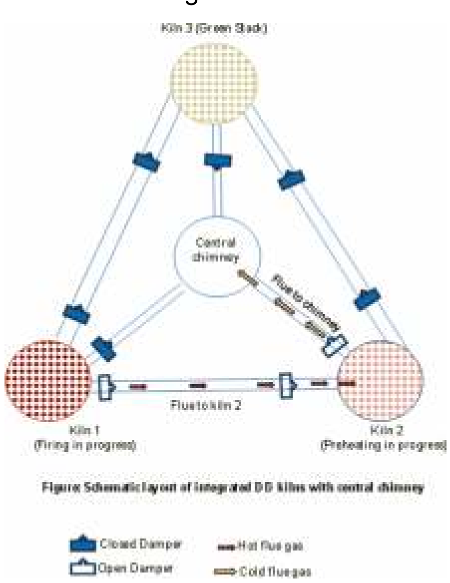
The refractory industries in the cluster do not use temperature indicators for monitoring and controlling furnace temperatures. At present, furnace temperature and fuel firing is done through human judgement and skill level of firemen. This can lead to substantial variations in furnace temperatures vis-à-vis actual requirements for different products. Thus it can lead to (1) over-firing which can result in higher fuel consumption and damage to products, and (2) under-firing which can result in sub-standard product quality. It is suggested that all DD kilns must install on-line temperature probes at least in three locations at crown level of the kiln to monitor furnace temperature and control fuel feeding as per requirements.

Improved damper system for downdraft kilns

The downdraft kilns use locally precast circular ceramic material as damper system which is a crude design. These dampers do not have appropriate fixtures for adjusting their levels to control draft kiln draft. Existing practice of damper control is crude and non-scientific resulting in negative draft and loss of heat through high temperature flue gases. It is suggested to use ceramic board based damper system along with mechanical arrangement for movement of damper plate to increase or decrease the draft as per requirements. This would further improve ease of work for firemen.

Preheating of green refractory by flue gas

Traditionally built existing downdraft kilns in the cluster are unscientific and lacks proper layout as well as dimensions are inadequate. The chimney height is also more resulting very high negative draft in the furnace after initial firing cycle as dampers are not suitable to control the draft. Owing these facts, high temperature flue gases from downdraft kilns are vented out to chimney without any heat recovery system in place. Combustion air for firing coal in downdraft kilns are obtained with the help of natural draft, which is generated by connected chimney to the furnace. It would be easily possible to recover sensible heat from exhaust flue gases by integrating existing downdraft kilns in a manner to ensure flue gases are directed from source kiln to another kiln, which is loaded with green refractory and next in line for firing. Hence, the waste heat available in flue gases can be effectively utilised to preheat green refractory without installing any waste heat recovery system which can lead to substantial fuel saving.



Preheating arrangement in DD kilns

Technology switch over for efficient firing

Adoption of tunnel kilns

The SEC in tunnel kilns is 866 kcal/kg as against of 2308 kcal/kg in DD kilns. It would be possible to reduce energy consumption by about 62% by switching over to tunnel kilns with existing product volume. Other advantages with tunnel kilns include kiln automation, better monitoring and control of operating parameters, higher yield and enhanced production volumes. The estimated energy saving at cluster level is about 14,539 toe per year with tunnel kiln adoption.

Adoption of chamber kilns

Another potential technology option available for DD kilns is switch over to chamber kilns. In a chamber kiln, exiting flue gases are directed to flow to immediate following chamber after which the gases join central flue path connected with chimney. The sensible heat in flue gases is recovered through preheating of refractories. Preheat temperatures of up to 1100°C are possible to achieve in chamber kilns and the temperature of exiting flue gases at chimney can be lowered to about 100°C. Thus the preheating of refractory product reduces the heat load requirements substantially leading to significant energy savings. The specific energy consumption in chamber kiln is 1339 kcal/kg and estimated to save around 56% of energy if refractory products are fired using chamber kilns. At cluster level, about 11,698 toe per year can be by switching from downdraft kilns to chamber kilns.

(2) Tunnel kilns

Use of low thermal mass cart

Green refractory products are loaded on to kiln cars to transfer inside tunnel kilns. Presently, kiln cars are made of metallic frame and refractory material resulting in higher dead weight and hence heat losses. Kiln cars can be fabricated using low thermal mass material which would help in reducing both dead weight of cars and heat losses. The weight reduction of the kiln carts in tunnel kilns provides significant scope to improve energy performance of tunnel kiln system. The following modifications can be incorporated to reduce the weight of the kiln cars:

- Replacement of refractory bricks with the hollow ceramic coated pipes at the supporting pillars for holding racks
- Use of ceramic fibre blankets at the base of the car instead of refractory brick base
- Use of cordierite (hollow) blocks to hold the raw-wares instead of solid refractory mass

Reducing the dead weight by about 30%, heat losses from kilns can be reduced substantially. The envisaged fuel saving with dead weight reduction of trolleys in tunnel kilns is about 3% of total heat input equivalent to 44 toe per year.

Enhanced insulation of tunnel kilns

The surface temperatures of firing zone of tunnel kiln are observed to be high leading higher heat losses and hence higher fuel consumption. It is suggested to introduce ceramic fibre blankets in tunnel kiln that would help in reducing heat losses from kiln surfaces.

Optimum furnace loading

The present level of loading of tunnel kilns was observed to be lower which may be attributed mainly to existing market conditions. It may be noted that various associated heat losses in tunnel kilns such as heat losses due to deadweight of trolley structure, surface heat losses, etc. would remain the same irrespective of loading of the kiln. Hence reduced loading would lead to higher specific energy consumption and hence higher production costs. It is suggested to plan optimum loading of tunnel kilns in order to minimise SEC levels.

Fuel switch over

The tunnel kilns in the cluster use petcoke as fuel. There is a significant potential to use other fuels such as processed rubber oil which may be explored by the refractory industries. The fuel switch over would help in reducing energy costs as well as close control of fuel firing.

Other energy saving measures

Other energy saving measures relevant for refractory industries in the cluster include the following:

- Power factor improvement with automatic power factor controller
- Installing energy efficient motors in different drives
- Use of clogged V-belts in place of flat belts
- Energy efficient lighting

Major stakeholders

The major stakeholders in Asansol refractory industry cluster include Refractory Manufacturers Association, West Bengal and MSME Development Institute (Durgapur).

Cluster development activities

The cluster has established a Special Purpose Vehicle (SPV) in the name of Bangabhumi Cluster of Refractories Association during September 2012. There are 34 registered members from refractory industries in Asansol. The SPV is yet to be fully equipped and is exploring financial support to establish as material testing hub for local refractory industries.

TECHNICAL SECTION

LIFE IMPROVEMENT JOURNEY OF GRANSHOT EJECTOR AT TATA STEEL KALINGANAGAR

**Mahasin Hossain[1], Subir Biswas[1], Prasanta Panigrahi[1], Prakash Mishra[1], Rajiv Kumar Singh[1], Santanu Saha[1] (1.Tata Steel Ltd, Kalinganagar)*

Abstract

Granshot is the best iron granulation technology in the world by which we can convert molten liquid metal into granules through rapid solidification technology. In granshot process Molten liquid hot metal pour to launder from Torpedo ladle, then it transfers to tundish. From tundish to water reactor tank molten metal flow controlled by Refractory. It's a continuous iron granules solidification process of molten metal. Iron granules transfer through ejector pipe with air & water pressure to the dewatering unit. The granule size is varying from 3-50 mm & weight of the granules is 10-250 gm. During transportation of granules ejector pipe ceramic lining got dislodge frequently due to abnormally high water & air pressure lead to huge impact force over the ceramic lining. Here design & property of ceramic material will have crucial role which should comprises of properties like high impact resistance property, high compressive strength, Zero water absorption, high abrasion resistance material.

Keywords: Granshot, Granshot ejector

1. Introduction

The granules are discharged from the lower end of the granulation tank by a specially designed air/water ejector. This ejector carries the solid granules at a high speed upwards above the granulation tank water surface, thus acting as a water lock, and discharge them onto a dewatering unit.

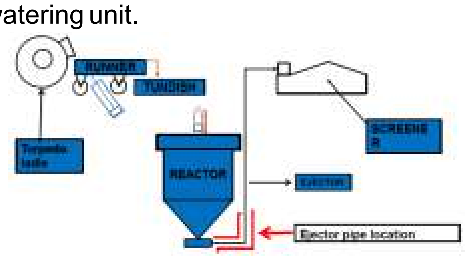


Fig. 1: Schematic process flow diagram of Granshot

During travelling of solid granules through ejector pipe due to high air & water pressure it hit the Ceramic lining at very high impact force & it leads to dislodge of Ceramic lining.

2. Failure analysis

2.1 Details of Granshot ejector

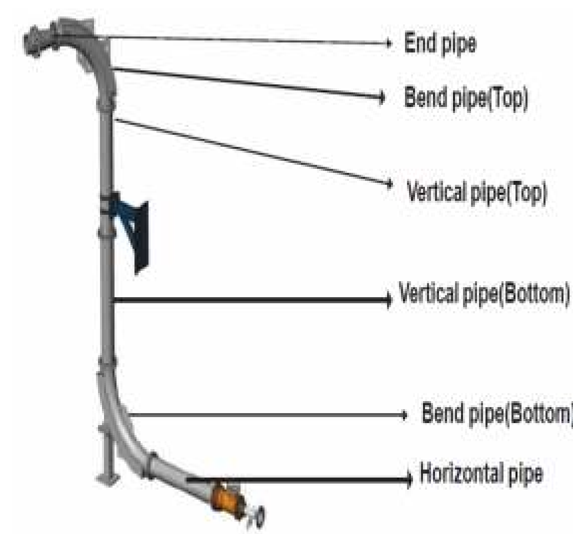


Fig. 2 General pipe arrangement of Ejector

Fig. 2 shows ejector consist of six segmented ceramic lined pipes i.e. one no's horizontal pipe, two no's bend pipes, two no's vertical pipes & one end pipe. Total length of the ejector is 8 meters. As per OEM design they gave target life of ejector is 60Mt production throughput of granshot but ejector start damages after granshot throughput of 10-11 Mt. Main impact area of ejector pipe is at horizontal pipe, bend pipe top & bottom. Refer Fig.3 We reach 26-72 Mt production after several repairs which lead to stoppage of production & process delay.

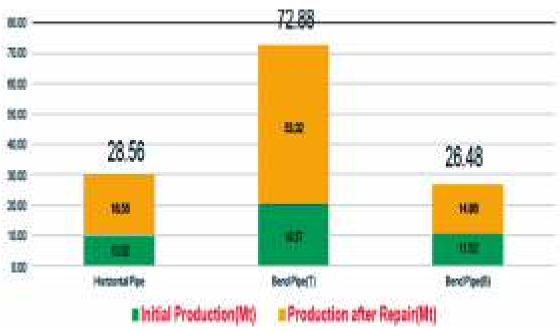


Fig. 3 Life of ejector at different area

Fig.4 Ejector damaged after 15000 Tons production

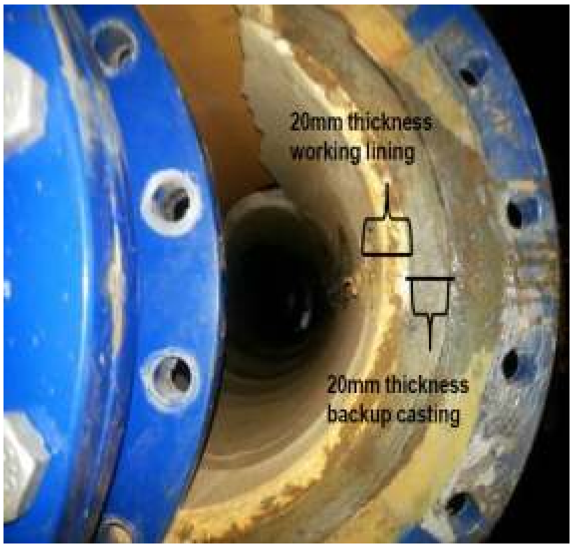


Fig. 5 Ceramic lining pattern of ejector

After dislodging of ceramic lining, it was observed that two layers of ceramic lining present in ejector. 1st layer is 20 mm back up castable material & 2nd layer is 20 mm high strength ceramic type material. To understand the nature of material we collect sample & test at our laboratory for further evaluation.

2.2 Material Test Result

Refer table no:1 lower density, high porosity it seems they have used 20 mm insulation type material at back up lining. In 20 mm working lining higher density, almost zero porosity & containing Zirconia, Alumina in chemical composition confirms that they have used high strength Fused cast zirconia corundum type material

Table no:1

Parameter	Unit	Backup Lining	Working Lining
Density	gm/cc	1.81	3.61
Porosity	%	25.21	0.43
Al_2O_3	%	3.17	45.32
SiO_2	%	76.31	16.99
ZrO_2	%		35.88
Fe_2O_3	%	1.04	0.37
CaO	%	8.5	0.26
MgO	%	0.04	0.29
TiO_2	%		0.07
MnO	%		0.005
CCS(Mpa)			390

2.3 Probable reason of failure

a) Operational Parameters:

The damage of Ceramic lining took place in all bend - area. In vertical pipe, the lining is intact. In the bend of 90° portion the additional force in generating due to change of direction of the granshot granules, which is a significant increase of force for very high discharge rate (as mentioned 6 tons/min) carried by water and air with a pressure of 6 bar. The present design is not capable to withstand the additional force created for change of flow direction and the working layer is cracking at bend. Details of operational parameters given in table no:2

Table no:2

Operational Parameters	Value
Compressed Air Flow rate (M3/Hr)	1300
Air Pressure (Bar)	5
Water Flow rate (M3/Hr)	465
Water Pressure (Bar)	5.25
Water temperature at flow (°C)	30
Particle Size of metal (mm)	3-50
Particle Shape	Oval and round
Production Discharge (In Tons/Mins)	6

b) Quality & design issue:

Working lining is made of very hard, fused cast zirconia corundum type material with very good abrasion resistance and almost zero porosity, density is as high as 3.61 gm/cc. The backup lining is made of much softer material with a density of 1.90, Porosity: 22 % and can be compressed under increase of pressure. At bend portion the backup lining is unable to provide uniform support to the working lining and hence the working lining dislodged. Working lining is brittle and it dislodge under uneven load.

3. Alternate material & design development

Based on failure analysis we have decided to work on alternate material which will have following properties like high CCS, zero porosity, high density, zero water absorption, high abrasive resistance & modify lining design with adequate strength to overcome the impact force of granshot granules.

3.1 Alternate material for ejector:

Refer table no:3 we choose 92% Al_2O_3 based Ceramic tiles which is having following properties like high abrasive resistance, equivalent BD with existing working lining material, Zero porosity, five times higher CCS. All this property makes this material suitable for application like granshot.

Table no:3

Parameter	Previous material Spec	Alternate material Spec
Al2O3(%)	51	92 Min
SiO2(%)	13	
ZrO2(%)	33	
Density(gm/cc)	3.61	3.63
CCS(Mpa)	400	1900
Porosity (%)	0.43	0
CMOR(Mpa)		310
Abrasion Resistance		0.1 gm max
Hardness (Moh's scale)		9

3.2 Modify lining design:

In previous design two types of lining material used (20 mm insulation back up & 20mm Zirconium corundum material). Due to low strength insulation, back up & water absorption in working lining, it's damaging frequently. So, we make a strong 35 mm single layer lining i.e. 92% Al2O3 based ceramic tiles which is having higher strength & zero water absorption.

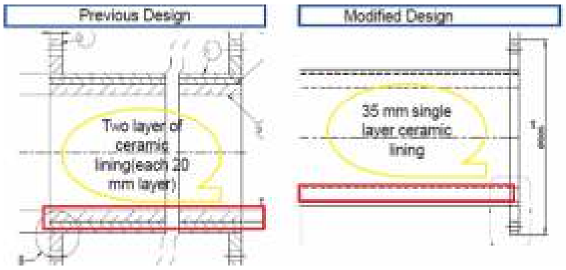


Fig.6 Comparative present & modified design

3.3 Installation of newly lined ejector:

Hollow cylindrical shaped ejector internal diameter is only 260 mm & it is very difficult to lining of Ceramic tiles. So, it was decided to be lining of the ejector in small segment wise & weld it after lining. Before lining based on contour different shaped of tiles made so that there will be no manual cutting during installation. For ejector, we considered 10.31 mm seamless MS pipe STD, 35mm 92% Ceramic tiles, 2.5 mm RTV Silicone bond material. RTV silicone is room temperature vulcanizing silicone rubber having hardness range 15-40 shore. RTV silicone bond material is very important as it is adhesive between tiles & also gives cushioning effect to working lining during impact of granshot granules from backup & shell. After completion of lining six no's of ejector installed at site.

Fig.7 Ejector bend pipe after completion of lining

Fig.8 Ejector after installation at site

4. Plant trial

4.1 Performance improvement:

After changing in lining design & quality we have taken full set plant trial.

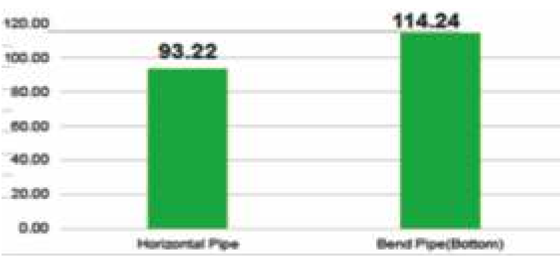


Fig.9 Life of ejector after changing quality & lining pattern

4.2 Condition of trial ejector after discard:

a) Horizontal pipe:

Fig.10 Ceramic tiles dislodged after achieving 3.26 times higher life in horizontal pipe

b) Bend pipe(Bottom):

Fig.11 Ceramic tiles dislodged after achieving 4.31 times higher life in bend pipe(bottom)

5. Conclusion:

Trial results confirms that alternate material is having very high abrasive resistance & zero water absorption which is the enabler to increase life throughput from 10-11 Mt to 93-114 Mt with no intermediate repair. Also change in lining design gives structural integrity which able to absorb high impact force of granshot granules. Due to improvement in throughput of ejector our breakdown time also reduced from 4.19 days/year to 0.62 days/year which leads to improve overall productivity.

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(Source: IREFCON20 Proceedings)

TECHNICAL SECTION

OPTIMISED DRY-OUT OF NO-CEMENT CASTABLES

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ABSTRACT

Cement-free castables have fast dry-out and excellent hot properties compared to cement bonded refractory castables. However, their green strength is often so low that handling becomes a challenge, particularly for larger pieces. Drying industrial-scale specimens are not straight forward and always more complicated than lab-scale samples. In this paper, the dry-out behaviour and explosion resistance of microsilica-gel bonded no-cement castables (NCCs) have been investigated and optimised for lab-scale specimens by applying various drying agents and subsequently tested in large industrial-scale specimens. The mechanism of fast dry-out was evaluated by TGA analysis and SEM characterisation. Replacing cement bond with microsilica-gel bond results in true fast dry-out and improved explosion resistance. The explosion resistance can further be significantly improved by using a specialty drying agent (EMSIL-DRY™); as demonstrated by the problem-free production of a perfect 400kg block of microsilica-gel bonded NCC using a fast firing schedule (20 to 850°C at a heating rate of 50°C/hr).

Keywords: Fast dry-out, microsilica-gel bond,no-cement castable (NCC), EMSIL-DRY™

1. INTRODUCTION

Refractory castables are normally cement bonded and require special attention during the first heat-up. When vapour pressure generated inside the refractory exceeds its mechanical strength, the result could be significant damage due to explosion and/or spalling. Vapour pressure increases potentially with the temperature in a closed liquid/vapour aqueous system, as described by Antoine's equation [(1)].

$$\log_{10} p = A - \frac{B}{C+T} \qquad (0 \text{ to } 374°C)$$

Fig.1 [(2)] shows the evolution of vapour pressure (P_v) as a function of temperature according to Antoine's equations and the typical green tensile strength for refractory castables are indicated. The dry-out process of cement bonded castables involves three stages: i) evaporation from room temperature to 100°C, ii) ebullition from 100 to ~300°C, iii) hydrate decomposition at a temperature above 250 - 350°C.

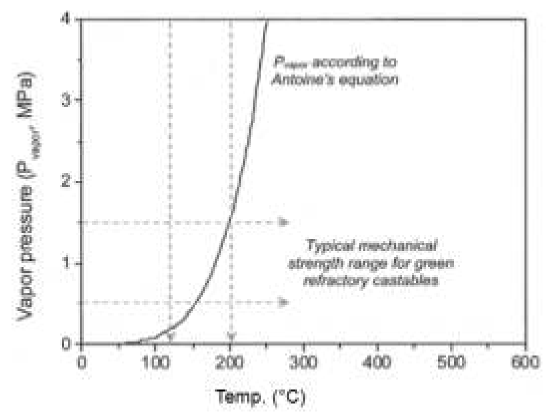

Fig.1: Vapour pressure (P_v) increases exponentially with the temperature according to Antoine's equation [(2)].

When the temperature in the sample reaches 100°C, the ebullition starts and leads to massive water loss, and the water removal is ruled by vapour pressure. This is the most critical dewatering step and spalling and/or explosion most likely takes place in this stage. Vapour pressure is dependent on the heating profile and the permeability and thickness of the refractory body. A high fraction of the water in cement bonded refractories is chemically bound which need to be fired at temperatures up to 600°C to remove it. Therefore, the heating profile for a refractory lining is normally divided into steps for safe removal of free water at lower temperatures and decomposition of cement hydrates at higher temperatures[3-4]. It has always been challenging to remove water from the centre of LCCs. Hence, optimisation of dry-out schedules and improvement in permeability of cement bonded refractories need special attention to reduce the risk of spalling and/or explosion.

NCC, such as colloidal silica bonded refractory castables are very interesting due to their fast dry-out and excellent hot properties. Yet their green strength is often so low that demoulding and handling after curing become a challenge, particularly for larger pieces as opposed to small laboratory test specimens[5-6]. Recent work by Elkem demonstrates that microsilica-gel bonded NCCs show improved green strength compared to colloidal silica bonded, excellent hot properties and exhibit fast dry-out performance compared to LCCs[7-11]. In microsilica-gel bonded no-cement castables, only a very small amount of the mixing water is retained after drying at 110°C, hence, most of the free water are removed by simple drying.

However, drying industrial-scale specimens are not easy and always more complicated than lab-scale samples. In this paper, tabular alumina based refractory castables have been chosen to investigate the dry-out behaviour and explosion resistance based on both lab-scale and industrial-scale trials. The following aspects are covered: i) effects of drying agent/anti-explosion agent on flowability and mechanical strength, ii) improvement in explosion resistance of microsilica-gel bonded NCC by introducing anti-explosion agent, EMSIL-DRY™, and iii) investigation of the fast dry-out mechanism using thermogravimetric analysis (TGA) and scanning electron microscopy (SEM) characterisation.

2. EXPERIMENTAL

2.1 Mix design

Table 1 shows the overall compositions of microsilica-gel bonded NCCs. Different fractions of tabular alumina (Almatis, Germany) were used as aggregate, and microsilica (Elkem Microsilica® 971U, Elkem, Norway) and SioxX®-Zero (Elkem, Norway) were used as binder. SioxX®-Zero is a tailor-made product for microsilica-gel bonded NCCs. Four types of drying agent/anti-explosion agent were used in the tests: i) three commercially available fibres, labelled Fibre-P1, -P2, -P3, and ii) one specialty fibre (EMSIL-DRY™ Elkem, Norway). EMSIL-DRY™ is a special polymeric fibre for refractory castables to speed up the drying and reduce the risk of spalling and explosion during heat-up. The water addition was 4.35% for all mixes.

Table 1: Mix design of tabular alumina based NCCs (wt%)

	REF	P1	P2	P3	EMSIL-DRY™
Elkem Microsilica® 971U	5	5	5	5	5
Cement (70% Al_2O_3)	0.5	0.5	0.5	0.5	0.5
Tabular alumina 0-6mm	82.5	82.5	82.5	82.5	82.5
Al_2O_3 fines	9	9	9	9	9
SioxX®-Zero	3	3	3	3	3
Fibre-P1		0.05			
Fibre-P2			0.1		
Fibre-P3				0.1	
EMSIL-DRY™					0.1

2.2 Experimental procedures

Self-flow and vibration-flow were measured after four minutes wet-mixing using the flow-cone described in ASTM C230 (height 50mm, not the 80mm self-flow cone described in EN 1402-4:2003). The self-flow value is the percentage increase of the diameter measured 90 seconds after removing the cone.

Lab-scale explosion resistance testing per Chinese Standard YB/T4117-2003 were carried out for all mixes. 50mm cubes are placed into a hot furnace at a pre-set temperature. The cubes are inspected after 30-minute exposure. The temperature at which cracks start to form or explosive spalling occurs is reported as the explosion resistance.

For industrial-scale explosion resistance tests, the castables were cast into larger moulds with dimensions of: i) 300x300x300mm (~80kg), and ii) 600mmx600mmx350mm (~400kg). The castables were de-moulded after one day and placed in the oven for further drying behaviour studies and/or explosion resistance tests. The heating schedule for the explosion test was 20 to 850°C at 50°C/hr; cooling from 850 to 20°C at 50°C/hr.

3. RESULTS AND DISCUSSION

3.1 Flowability

Self- and vibration-flow measurementsare summarised in Fig.2. The addition of Fibre-P2, -P3 and EMSIL-DRY™ is 0.1% while Fibre-P1 had to be reduced to 0.05% to achieve similar flow. The self-flow and vibration-flow values with fibres at a water addition of 4.35% are approximately 40% and 100-120%, respectively. When 0.1% Fibre-P1 was used, the self-flow value dropped to a mere 12% and caused problems to cast samples.

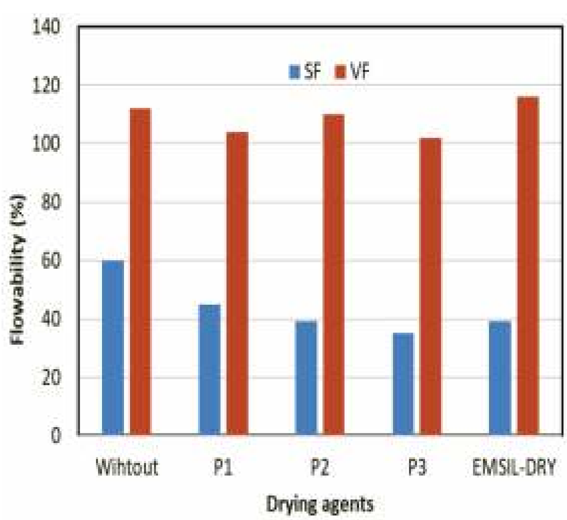

Fig.2: Flowability of microsilica-gel bonded NCCs with different drying agents.

Table 2 shows the green crushing strength (CCS) and modulus of rupture (CMOR) (24hrs at >90% RH and 20°C). The microsilica-gel bonded NCCs with EMSIL-DRY™ has adequate green strength, with CCS of 11.2 MPa, slightly higher than the others. The results show that the type of fibres have some impact on strength development.

Table 2: Mechanical strength after demoulding and drying of tabular based NCCs with various fibres (MPa)

		REF	P1	P2	P3	EMSIL-DRY™
20 °C/24 hrs	CMOR	2.6	2.0	2.9	3.4	3.1
	CCS	8.9	9.7	8.6	8.5	11.2
110 °C/24 hrs	CMOR	6.4	6.3	7.4	5.7	7.1
	CCS	44.6	32.5	30.4	41.6	42.8

3.2 Lab-scale explosion resistance

Microsilica-gel bonded NCCs with different drying agents were used to further investigate the drying behaviour. Table 2 shows the lab-scale explosion test results of both "wet" and "dried" samples tested according to Chinese Standard YB/T4117-2003. The samples were cured for 24hrs at room temperature and 100% relative humidity before de-moulding. The freshly de-moulded samples are labelled "wet" and samples further dried for 24 hrs at 110°C are called "dried".

Table 2: Explosion resistance of microsilica-gel bonded NCCs

	Wet (20°C/24hr)				
Temp. (°C)	*REF*	*P1*	*P2*	*P3*	*EMSIL-DRY™*
300	*v*	*v*	*v*		
350	*x*	*x*	*v*		
400		*x*	×	*v*	*v*
450				*v*	*v*
500				×	*v*
	Dried (110°C/24hr)				
1000	*v*	*v*	*v*	*v*	*v*
1200	*v*	*v*	*v*	*v*	*v*

√: passed; x: failed

All "dried" samples show excellent explosion resistance and pass the test at 1200°C. The good performance is attributed to a stable bond phase and the low amount of residual water in the bond phase. When the "wet" samples were tested, good explosion resistance was achieved for the microsilica-gel bonded NCC containing anti-explosion agents. For the REF mix and the mix with low dosage Fibre-P1, the specimens only survived the test at 300°C, and exploded at 350°C. The mix with EMSIL-DRY™ had the best explosion resistance. This indicates that EMSIL-DRY™ causes the fastest dewatering of the NCC samples.

3.3 Industrial-scale explosion resistance

To further improve and understand the explosion resistance, two types of larger blocks with and without fibre addition were produced, ~80kg (300mm cubes) and ~400kg (600x600x350mm). All blocks were cured at room temperature for 24hrs, then de-moulded and put directly into the furnace. The heating schedule was 20 to 850°C at 50°C/hr; cooling from 850 to 20°C at 50°C/hr.

Fig.3 shows ~80kg (300mm) microsilica-gel bonded NCC cubes without drying agent before and after the explosion resistance test. With no addition of drying agent, the 80kg block disintegrated during the test and parts of the block was completely pulverised.

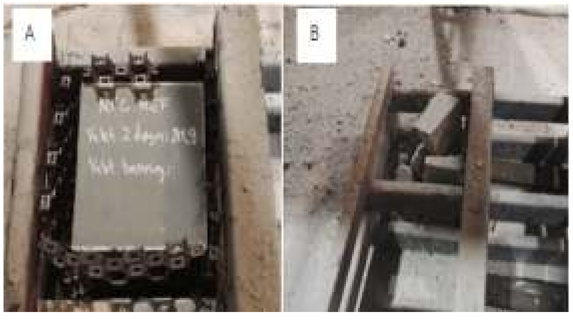

Fig.3: ~80kg block (A) before and (B) after explosion resistance test (from 20 to 850°C at 50°C/hr).

Fig.4 shows ~80kg (300mm) cubes containing Fibre-P1, -P3 and EMSIL-DRY™ after explosion resistance test at 850°C. The NCC with Fibre-P2 exploded and looked like the cube with Fibre-P1. Further an NCC with 0,1% Fibre-P1 was also tested and this exploded. The castables with EMSIL-DRY™ and Fibre-P3 show good explosion resistance and the ~80kg blocks were perfect after the test, whereas the blocks with Fibre-P1 and -P2 disintegrated completely. This confirms that the type of fibres has strong impact on explosion resistance and that the risk of explosion could be high when an improper fibre is used.

Fig.3: ~80kg block (A) before and (B) after explosion resistance test (from 20 to 850°C at 50°C/hr).

Fig.4 shows ~80kg (300mm) cubes containing Fibre-P1, -P3 and EMSIL-DRY™ after explosion resistance test at 850°C. The NCC with Fibre-P2 exploded and looked like the cube with Fibre-P1. Further an NCC with 0,1% Fibre-P1 was also tested and this exploded. The castables with EMSIL-DRY™ and Fibre-P3 show good explosion resistance and the ~80kg blocks were perfect after the test, whereas the blocks with Fibre-P1 and -P2 disintegrated completely. This confirms that the type of fibres has strong impact on explosion resistance and that the risk of explosion could be high when an improper fibre is used.

Fig.4: ~80kg (300mm) cubes with different fibres after explosion resistance test (from 20 to 850°C at 50°C/hr). A) Fibre P3, B) EMSIL-DRY™ and C) Fibre-P1. The NCC with Fibre-P2 looked like cube C) Fibre-P1.

It is difficult to differentiate the effect of EMSIL-DRY™ and Fibre- P3 on the explosion resistance since both blocks were perfect after the test (Fig.4). Hence, we carried out further explosion resistance testing on ~400kg blocks (600x600x350mm) containing both EMSIL-DRY™ or Fibre-P3. Fig.5 shows the blocks after the tests. The block containing EMSIL-DRY™ performed perfectly at a heating rate of 50ºC/hr while the one with Fibre-P3 disintegrated into several pieces.

Fig.5: ~400kg blocks after explosion testing at 850°C. A) Fibre-P3 and B) EMSIL-DRY™

The explosion resistance tests show that both lab-scale and industrial-scale NCC with EMSIL-DRY™ exhibit the best explosion resistance. A good correlation between the lab-scale and industrial-scale test results has also been observed. In other words, lab-scale explosion resistance tests may provide good guidance for industrial installation. Not surprisingly, the higher the temperature at which the lab-scale specimens survive, the better the explosion resistance becomes for large blocks.

3.4 Mass loss, Differential Scanning Calorimetry (DSC) and Scanning Electron Microscopy(SEM) characterisation

To understand the mechanism of fast dry-out behaviour, mass loss and DSC characterization were carried out for EMSIL-DRY™ and Fibre-P1.The samples were heated to 600°Cin oxidizing environment with air flow of 50 ml/minat a heating rate of 5°C/min. Fig. 6 and 7 show the mass loss (%) and DSC(mW/mg)as a function of firing temperature of EMSIL-DRY™ and Fibre-P1, respectively.

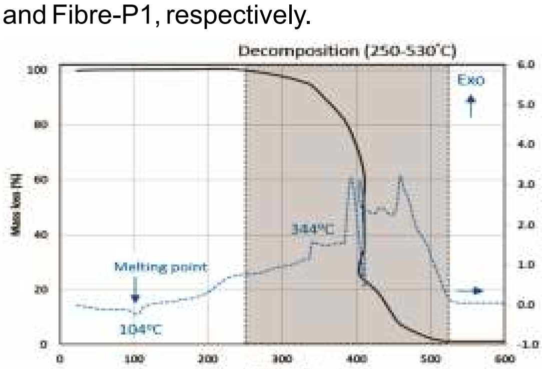

Fig. 6 Mass loss (%) and DSC (mW/mg) of EMSIL-DRY™ during heat up.

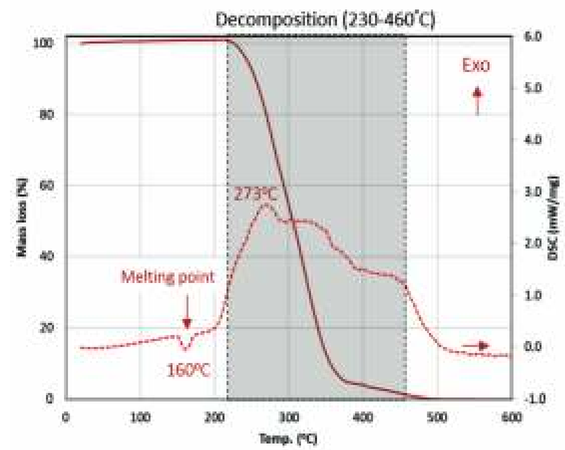

Fig. 7 Mass loss (%) and DSC (mW/mg) of Fibre-P1 during heat up.

Fig. 6 shows that the melting point of EMSIL-DRY™ is 104°C and that decomposition takes place from 250°C-530°C. Some 80% decomposes between 350-450°C. In contrast, the melting point ofFibre-P1 (Fig. 7) is about 165°C,decomposition temperature range is 230-460°C, andapproximately 80% of Fibre-P1 disappeared between 250-350°C. Both mass loss and DSC results confirm that EMSIL-DRY™ melts at a much lower temperature and degrades at a higher temperature in oxidizing environment compared to Fibre-P1 Consequently, as seen in our experiments, explosion/spalling resistance of NCCs has been significantly improved when EMSIL-DRY™ is added as a drying agent.

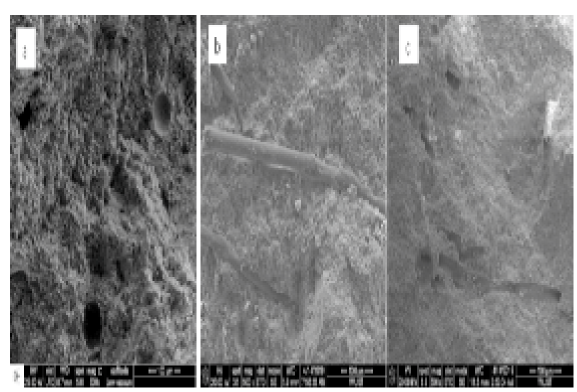

Fig.8: SEM of fractured surface of NCC samples heated at 120ºC for 12hrs. a) NCC REF, b) NCC with Fibre-P1, and c) NCC with EMSIL-

DRY™

Furthermore, the NCC specimens were fired at 120ºC for 12hrs and their fractured surfaces were used for SEM characterisation, as presented in Fig. 8. When the temperature exceeds the melting point of EMSIL-DRY™ numerous needle-like channels are produced, facilitating water removal during the ebullition stage. As seen, Fibre-P1 still remains intact at 120ºC with no channels formed. This indicates that the vapour pressure inside the NCC specimen with EMSIL-DRY™ should be much lower than the reference and the one containing Fibre-P1.

All this demonstrates that the explosion resistance/drying behaviour of microsilica-gel bonded NCC is significantly improved.EMSIL-DRY™ contributes to faster dewatering in the early stage of the firing process (ebullition stage at 110-300°C, as illustrated in Fig.1), mainly due to lower melting point and lower extra pressure from fibre decomposition. It indicates that true rapid firing is possible for NCCs.

4. CONCLUSIONS

Based on our studies of flowability, drying behaviour, explosion resistance, DSC and SEM characterisation of microsilica-gel bonded NCCs with and without drying/anti-explosion agents, the following conclusions can be drawn.

- The types of drying agent have significant impact on flowability and drying out behaviour of refractory castables.
- The microsilica-gel bond system contains only small amounts of bound water. Once the free water is removed, the castables can be fired at very high heating rates.
- With introduction of EMSIL-DRY™, the drying rate has been significantly improved.
- The microsilica-gel bonded NCC with EMSIL-DRY™ has excellent explosion resistance.

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(Source: IREFCON20 Proceedings)

STATISTICS

EXPORT OF REFRACTORIES FROM INDIA:

REFRACTORY CEMENTS-MORTARS-CONCRETES AND SIMILAR COMPOSITION INCLUDING DOLOMITE RMMING MIX,Unit: KGS

S.No.	Country / Region	Values in US$ Million			Quntity in thousands			
	2021-2022		2022-2023		2021-2022		2022-2023	
1	BANGLADESH PR	8.78	U ARAB EMTS	11.11	SAUDI ARAB	24,951.28	SAUDI ARABIA	34,914.21
2	U ARAB EMTS	6.83	BANGLADESH PR	9.87	U ARAB EMTS	19,629.61	NEPAL	29,558.74
3	NIGERIA	6.28	NIGERIA	8.95	BANGLADESH PR	16,429.99	U ARAB EMTS	21,599.76
4	SAUDI ARABIA	6.16	SAUDI ARAB	4.2	KENYA	15,032.40	KENYA	18,614.26
5	KENYA	3.98	KENYA	3.47	NEPAL	14,870.21	BANGLADESH PR	16,057.17
6	NEPAL	2.62	NEPAL	2.5	NIGERIA	11,295.61	GHANA	10,300.85
7	OMAN	2.11	OMAN	2.08	GHANA	9,055.82	TANZANIA REP	5,525.67
8	TANZANIA REP	1.58	TANZANIA REP	1.9	QATAR	6,258.37	ANGOLA	5,217.49
9	GHANA	1.56	GHANA	1.83	OMAN	6,090.34	JORDAN	4,652.45
10	INDONESIA	1.29	INDONESIA	1.13	ANGOLA	5,272.71	OMAN	4,472.58

SILICA BRICKS AND SHAPES Unit: TON

S.No.	Country / Region	Values in US$ Million			Quntity in thousands			
	2021-2022		2022-2023		2021-2022		2022-2023	
1	BRAZIL	0.71	U S A	0.85	NEPAL	22.96	BHUTAN	5.61
2	SAUDI ARAB	0.48	BRAZIL	0.77	SAUDI ARAB	1.89	SAUDI ARAB	2.22
3	OMAN	0.3	SAUDI ARAB	0.62	OMAN	1.10	U S A	0.78
4	JORDAN	0.23	CHINA P RP	0.3	BRAZIL	0.85	JORDAN	0.71
5	JAPAN	0.12	VIETNAM SOC REP	0.23	JORDAN	0.72	OMAN	0.71
6	COTE D' IVOIRE	0.11	JORDAN	0.22	KENYA	0.64	BRAZIL	0.64
7	MOZAMBIQUE	0.11	OMAN	0.2	COTE D' IVOIRE	0.43	NEPAL	0.56
8	NEPAL	0.09	COTE D' IVOIRE	0.13	MOZAMBIQUE	0.40	COTE D' IVOIRE	0.51
9	KENYA	0.08	JAPAN	0.12	SINGAPORE	0.25	CHINA P RP	0.42
10	KUWAIT	0.06	NEPAL	0.11	KUWAIT	0.24	MOZAMBIQUE	0.36

(Source: Min. of Commerce, Govt of India)

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3. The print area shall be 16cm width X 24.5 cm height.
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6. The sectional or sub-heading should be 10 point “Arial” Bold, e.g. **Effect of High Temperature**.
7. The body typing should be 10 point “Arial” Normal, e.g. The factor affecting the lining life
8. References are to be numbered in chronological order as cited in the text and should be given in 10 point “Arial” Normal, at the end of the article. The format should be:- surname and name of the author first, followed by the title of the book/article, the title of the paper/ publication, volume number, issue number, page and year of publication.
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