International Research Science and Development Center

International Research Science and Development Journal

www.IRSDJournal.com

International Research Science and Development Journal
Vol. 1, No. 1, 2020, pp. 60-71.
ISSN 2348-3008

The process of producing sponge iron in rotary furnaces from a mechanical and chemical point of view

José Carlos Cherel[1] . Eduarda Martinho[1]

[1] Centre o Engineering, Department of Engineering, University Portugal, Portugal

Abstract

The importance of iron and steel in global development is such that it can be said that iron is the foundation of today's civilization. Frequency, low price, recyclability, high strength, as well as alloying ability, have created a variety of features in its use. Globally, iron ore is the most important feedstock for tall furnaces and oxygen furnaces (BF-BOF), accounting for 65.4% of global crude steel production in 2005. But to use this method, various processes must be done on the raw material, which requires a high amount of investment in infrastructure. In addition, it has created many environmental problems and the period of exploitation is long. Sponge iron is a better alternative to scrap in EAF / IF steelmaking units because of its homogeneous nature, optimal productivity and lower coke consumption. Sponge iron can replace steel scrap in the LD converter as a coolant. Not a firefighter. It does not contain harmful or waste elements such as copper, zinc, tin, chromium, tungsten, molybdenum, etc., which are usually present in steel scrap. Sponge iron has less sulfur and sulfur. Sponge iron is produced by non-coking coal through the process of regenerating iron ore in a rotary kiln. This paper examines the production process of sponge iron in rotary furnaces from a mechanical and chemical perspective.

Keywords: Sponge iron, rotary kilns, alloying, iron ore regeneration.

Introduction:

1. Introduction

Globally, iron ore is the most important feedstock for tall furnaces and oxygen furnaces (BF-BOF), accounting for 65.4% of global crude steel production in 2005. But to use this method, various processes must be done on the raw materials, which requires a high amount of investment in infrastructure. In addition, it has created many environmental problems and the period of exploitation is long. To overcome the shortcomings of the BF-BOF process, the EAF steelmaking method was developed, which has also had a long life. The share of arc steel production in global crude steel production increased from 26.6% in 1988 to 33.1% in 2005. The rising trend in scrap prices and its shortage has led to the acquisition of new technologies and the production of a suitable charge in the form of sponge iron (DRI direct iron regeneration). Sponge iron is obtained by direct regeneration of iron ore, the grade of which is between 84% and 95% [1].

Revival removes or destroys oxygen in the iron ore and forms the rock in the form of a honey comb or a porous spongy structure, which is why it is called sponge iron. Sponge iron is mainly used in steel production as a by-product. Sponge iron is actually one of the most important links in the steel production chain from mining to the production of final steel products. The main reason for the production of this product is to create a suitable raw material for charging electric arc furnaces for refining and producing steel [2]. Almost all sponge iron produced in the world is used for consumption in steel arc furnaces. Numerous methods have been proposed for the production of sponge iron in small capacities (below 150,000 tons per year), which are generally based on the direct reduction of iron by thermal coal [3]. The most popular of these methods is the SL / RN furnace. Another popular method is the tunnel kiln method. On the other hand, the high flexibility of this method compared to the input feed, the lack of need for pelletizing process, as well as the inactivity of the iron produced in this way and the possibility of selling the product as a middle product are other factors that lead to choosing the method of kiln reduction. They become a tunnel. According to the stated contents and with the aim of increasing the added value of the resources available in the country, one of the most suitable and famous methods for producing sponge iron in low capacities (below 150 thousand tons per year) is the tunnel kiln method [4].

2. Growing demand for sponge iron

In a world where iron stoves are loaded or fed with iron ore and arc furnaces and alkaline oxygen furnaces with scrap iron, these raw materials are the main raw materials for steelmakers. But markets for iron-containing raw materials appear to be smaller than alternative metals, such as sponge iron and hot briquettes. However, 2013's Global Direct Rehabilitation Statistics, published by Midrex Technology, shows that 75.2 million tons of alternative iron ore were produced in that year. Future opportunities for increased production for sponge iron and to some extent cast iron depend on the growth of electric arc steelmaking. Arc steelmaking capacity outside China has grown by 5 to 6 percent in the last 30 to 40 years [5]. The World Iron and Steel Association believes that this growth is likely to continue, and that we will see an increase in demand for sponge iron and other slow-moving raw materials. Spatially, sponge iron accounts for 12 to 15 percent of the total total charge or power supply of all electric arc steel mills in operation worldwide. In the future, the current production of sponge iron in the world is expected to increase from 75 million tons last year to 140 million tons by 2025, so that it can meet the growth of projected demand by then outside China [6]. According to global statistics, Iran is the second largest producer of sponge iron in India after India. This trend has continued since 2017. Sponge iron is currently trading at a global price of around $ 310 and a domestic price of $ 300 FOB in Bandar Abbas. What is ahead this year is an increase in demand for sponge iron from domestic steelmakers. This increase is not only in demand, but this year we are seeing an increase in the supply of sponge iron due to the joining of several development projects to sponge iron producers. Bullion producers were produced under the nominal capacity last year; but for the new year, they have a production plan for full capacity [7]. Therefore, the demand for ingots for the purchase of sponge iron is also increasing. In the previous year, sponge iron was exported by the producers of this product; But Sirjan Steel's Jahan-e-Foolad program aims to meet domestic demand first and foremost. However, the export price of sponge iron is higher than the domestic price; But our preference is to prioritize the supply of steel ingot producers domestically. With the arrival of Neyriz Steel and Sabzevar Steel projects, the equivalent of 1.6 million tons was added to the country's sponge iron production capacity, and the distance between the mentioned rank and India will be reduced to 2.29 million tons [8]. The volume of production in India and Iran was 24 million 390 thousand tons and 20 million 500 thousand tons at the end of 2017, but it should be noted that India for 2018, plans to increase production by 7% and achieve production It has 26 million tons of sponge iron, which will affect the distance between the two countries. However, Iran has previously been a leader in the production of this product. He continued: "Considering the price of the dollar and the difference between the price of sponge iron in the country and its global price, the excess export of sponge iron production is valuable for its producers." [9].

3. Reasons to use sponge iron

The use of sponge iron in areas where there is limited scrap supply but sufficient access to natural gas for recovery has always been a reasonable reason to use it; however, the supply or allocation of natural gas has become increasingly competitive in areas such as the Middle East. Other reasons for using sponge iron, hot briquettes and cast iron are as follows [10]:

• Sponge iron is a better alternative to scrap in EAF / IF steelmaking units because of its homogeneous nature, optimal productivity and lower coke consumption.

• Sponge iron can replace steel scrap in an LD converter as a coolant.

• Not a fire extinguisher. It does not contain harmful or waste elements such as copper, zinc, tin, chromium, tungsten, molybdenum, etc., which are usually present in steel scrap.

• Sponge iron has less sulfur and sulfur.

• The DRI process has the ability to use substandard charcoal with good reaction properties, which is unacceptable for traditional steelmaking.

• The use of DRI makes it possible to consume substandard scrap as part of rechargeable materials in electrical steelmaking without affecting the quality of the steel.

• Due to its specific composition, the use of DRI / HBI makes it possible to accurately predict the final analysis from the beginning of the continuous feeding of sponge iron.

• Productivity has been increased due to the coordinated size of DRI. The iron present in the form of oxide in sponge iron reacted with a carbon bath, which led to the effect of intense boiling and better heat transfer and accelerated the reaction of slag / metal during steelmaking. As a result, bathroom alignment is improved and leads to less hydrogen and nitrogen in the steel.

Low waste materials are slow-release raw materials derived from iron ore and the production of higher quality steels (such as hot-dip galvanized steels or SBQs). Advanced high strength can be considered as an element that always plays a role in the competition between aluminum and steel. If price is a priority, the percentage of slow-acting raw materials in the charge can reduce the waste elements in the scrap. Therefore, in order to compensate for the consumption of cheaper scrap grades, a balance must be struck by adding better quality raw materials.

Experts point out that the price difference between scrap and low-grade raw materials is less important. Research shows that spending $ 2 to $ 3 per ton can reduce the cost of steelmaking. Contrary to the higher purity of casting, it is sold at a lower premium scrap, which correlates with the change in the price of scrap iron. The price of hot briquettes is equivalent to a certain grade of scrap iron. More efficiency can be achieved by adding slow-acting raw materials, and many steelmakers prefer to minimize the amount of cleaning required to achieve the correct final grade for the production of pure primary molten steel. Other technical advantages include charge-to-furnace homogeneity and slag formation.

4. Sponge iron production situation in Iran and the world

Iran is currently the second largest producer of sponge iron by direct recovery after India. After India and Iran, Venezuela and Mexico are the third and fourth largest producers of sponge iron. The production of sponge iron in the world in 2012 by various methods of reduction (use of natural gas and coal) has reached 68.2 million tons. The growth of sponge iron production in India due to the abundance of coal mines that also use rotary furnaces and directly expose iron ore to regenerative gas produced from coal has caused the share of sponge iron production in this method in The world will rise to 25.7 percent [6].

Among the various methods of direct regeneration that use natural gas, the production of spider iron by the Madre method has developed significantly. The continuous fruiting of sponge iron in electric furnaces and electric arcs, and the possibility of increasing production efficiency due to modern technologies, have led to the launch of several other Madre units in the last two decades in various countries around the world. Sponge iron produced by various methods of using natural gas in the world, the share of Madre method has been more than 80% [9].

5. Explanation of sponge iron production process

The most important raw materials for the production of sponge iron are oxides such as iron ore / pellets, coking coal (with high reactive properties) and molten materials such as lime and dolomite. Care and precision must be exercised. Economical production of sponge iron can also be achieved by using high purity pellets and low phosphorus levels at an economical price [10].

Sponge iron is produced by non-coking coal through the process of regenerating iron ore in a rotary kiln. Revival takes place at a predetermined temperature and controlled atmospheric pressure. Incoming materials such as iron ore, coking coal (with high reactivity) and molten materials such as limestone and dolomite in calibrated sizes are fed into the kiln with the help of weight and volume feeders. Due to the inclination and rotational motion of the rotary furnace, the raw materials move slowly from the end of the power supply to the end of the discharge or charging point. During the movement of the iron ore, along with the previously heated coal, it is converted to DRI. The direct material is then discharged to a rotating cooler and cooled there. The temperature of the cooled product is about 80 که C, which is discharged from the cooler and then taken to the separation and relocation system. This product, which includes sponge iron with magnetic materials such as charcoal, etc., is separated by sieve in different sizes and then magnetically separated by a magnetic separator, then sponge iron is poured into a tank and sent out [11].

6. Advantages of using sponge iron in rotary kilns

By adding sponge iron to scrap in the feed tank, an arc furnace process significantly reduces impurities such as sulfur and phosphorus. By diluting the charging composition, the need for purification decreases and as a result, metallurgical operations inside the furnace become easier and increase the efficiency of the furnace. It has often been shown that if the charge is sufficiently dilute, it can be completely purified in the smelting operation of the furnace itself, thus increasing productivity.

- Continuous power supply: Continuous power supply of DRI to an EAF compared to charging one hundred percent scrap in the same conditions to the furnace increases the power or power.

Due to the heterogeneous nature of the scrap and the continuous change in the length of the arc between the electrode and the scrap, it causes severe fluctuations in the scrap melt. It has been shown that such extreme fluctuations reduce the power of the input power. On the other hand, continuous DRI melting reduces the power consumption of 15 kilowatt hours per ton of DRI produced using UHP transformers.

- Hot charging of sponge iron: Hot charging of sponge iron is one of the effective ways to reduce the cost of production of each ton of molten steel because it reduces electricity and electrode consumption. In addition, the DRI's hot charge increases the efficiency of the DRI's melting unit. In India, the hot DRI charging technology is one of the innovations of Essar, and it consumes about 120 kilowatt hours per ton of energy by consuming hot DRI by EAF at a temperature of 650 degrees Celsius in iron.

Other advantages

Low power consumption:

The use of DRI in comparison with scrap reduces the consumption of electrodes for the following reasons:

Scrap fall leads to an increase in fracture that is much less than when DRI charging is used.

- Using DRI increases productivity in the furnace. Due to the high amount of carbon monoxide (CO) in the furnace, the oxidation of the electrode decreases.
- Low oxygen consumption does not require much oxygen when scrap is reduced.

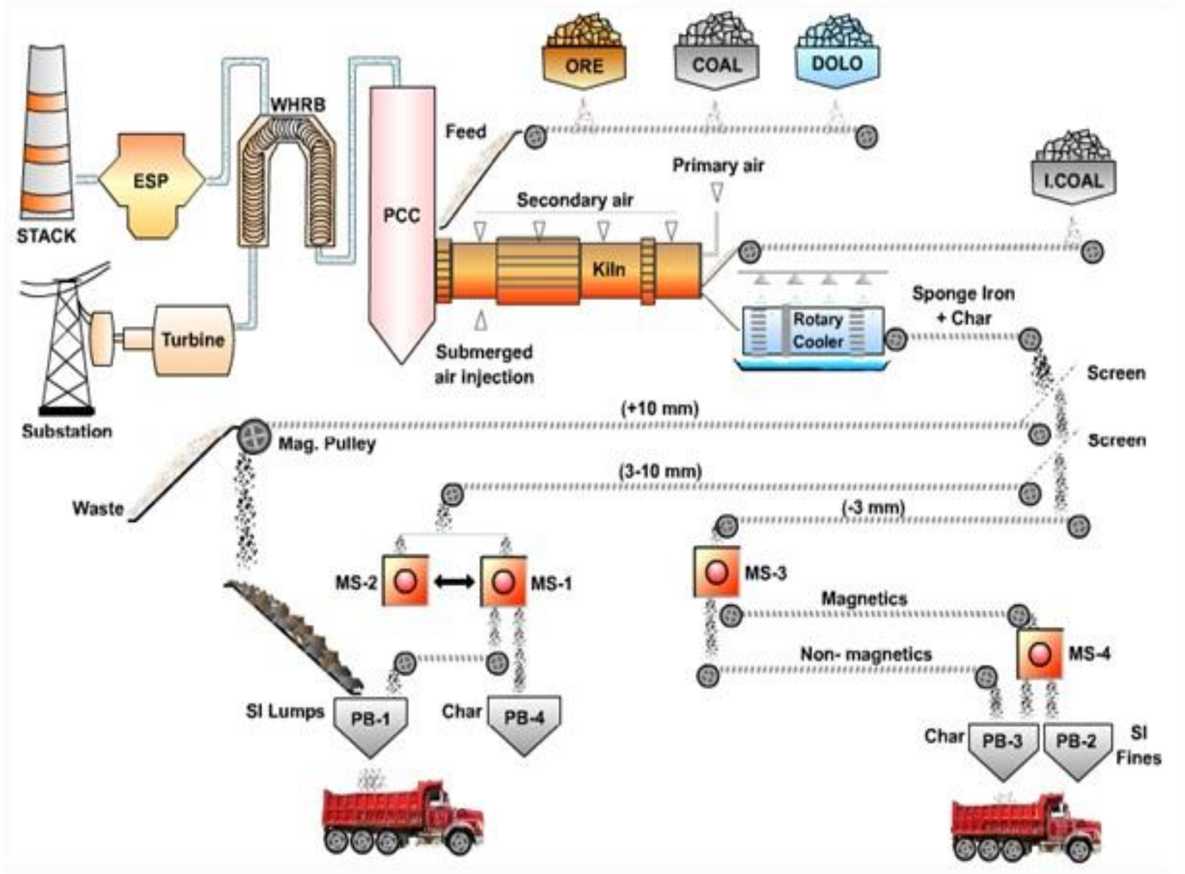
The input oxygen in DRI is not related to non-regenerative oxides.

Insufficient iron oxide in DRI is sufficient to meet the slag needs of iron oxides.

In addition to the above, the use of DRI in the charge combination reduces time and refractory consumption.

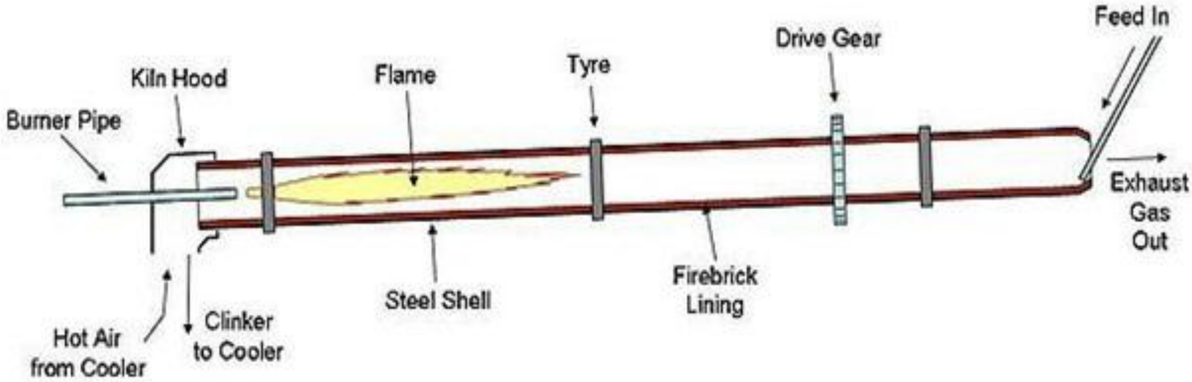
7. Schematic design of a sponge iron smelting iron factory

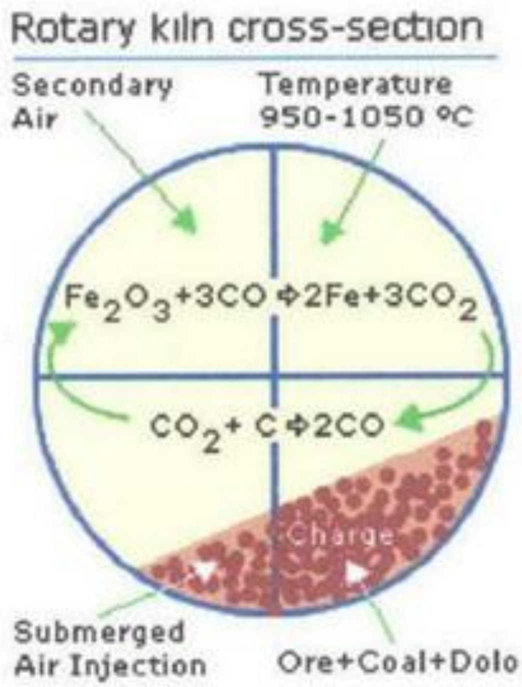
Sponge iron is produced by non-coking coal through the process of regenerating iron ore in a rotary kiln. Revival takes place at a predetermined temperature and controlled atmospheric pressure. Incoming materials such as iron ore, coking coal (with high reactivity) and molten materials such as limestone and dolomite in calibrated sizes are fed into the kiln with the help of weight and volume feeders. Due to the inclination and rotational motion of the rotary furnace, the raw materials move slowly from the end of the power supply to the end of the discharge or charging point. During the movement of the iron ore, along with the previously heated coal, it is converted to DRI. The direct material is then discharged to a rotating cooler and cooled there. The temperature of the cooled product is about 80 که C, which is discharged from the cooler and then taken to the separation and relocation system.



This product, which includes sponge iron with magnetic materials such as charcoal, etc., is separated by screening to different sizes and then magnetically separated by a magnetic separator, then the sponge iron is poured into a tank and sent out.

The schematic diagram of the sponge iron plant is shown below, as it is known that the main unit in the plant is a unit in which the three raw materials of iron ore, coal and dolomite are combined and reactions take place between them.





As shown in the figure below, all reactions occur in rotary cylindrical furnaces around their axis and have a gentle slope (below 5 degrees) relative to the earth, hematite or magnetite rocks or pellets containing coal and limestone or The dolomite is inserted into the furnace and heated while moving in the opposite direction of the gas flow, and at a temperature of about 1100 C to about 92% reduction, and is converted to sponge iron.

Weight (t)	Power (kw)	Rotating speed)(r/min	Capacity (t/h)	Shell size			)Model (m
				(%) Slope	Length (m)	)Dia (m	
47.5	18.5	0.39-3.96	0.9-1.3	3	33	1.4	33×1.4
52	22	0.26-2.63	1.2-1.9	4	36	1.6	36×1.6
78.2	30	0.16-1.62	1.9-2.4	4	45	1.8	45×1.8
77.59	30	0.29-2.93	1.65-3	4	39	1.9	39×1.9
119.1	37	0.23-2.26	2.5-4	3	40	2	40×2.0
128.3	45	0.21-2.44	3.4-5.4	3.5	45	2.2	45×2.2
149.61	55	0.44-2.44	9.0-10.5	3.5	40	2.5	40×2.5
187.37	55	0.62-1.86	6.25-7.4	3	50	2.5	50×2.5
196.29	55	0.48-1.4	6.9-8.5	3.5	54	2.5	54×2.5
198.5	55	0.10-1.52	10.0-11.0	3.5	42	2.7	42×2.7
201.58	55	0.437-2.18	12.5-13.5	3.5	44	2.8	44×2.8
210.94	75	0.5-2.47	12.8-14.5	3.5	45	3	45×3.0
237	100	0.6-3.448	25.6-29.3	3.5	48	3	48×3.0
310	100	0.3-2	12.3-14.1	3.5	60	3	60×3.0
278	125	0.6-3	40.5-42	4	50	3.2	50×3.2

8. Conclusion:

• Small recovery and steelmaking units can have the following advantages:

• Less need for investment and valuation and therefore the possibility of attracting private sector capital

• Ability to work with simple technology in some processes and create direct and indirect employment for local people

• Construction of these units in scattered areas (preferably in the vicinity of mines) and job creation in these areas.

• Consumption of relatively less infrastructure facilities for each unit

• Use simpler and more limited lines of communication for each unit

• Short-term engineering activities - supply and installation of equipment and facilities

• Production of carbon-containing sponge iron, which can be useful in steelmaking

• Ability to use different iron ore and in different forms such as rock molds, pellets and stone grains and lumps

• Existence of resources rich in substandard coals in the country and low costs of coal mining

• Creating a consumer market for cocoa coals

• Low coal prices

• Possibility of constructing factories with low production capacity, lower cost of establishing a factory and lower initial capital than other methods

• In the early stages of development, due to the relatively high heat loss of these furnaces, it was not widely used, but with the passage of time and the emergence of new technologies, this very old method was introduced at the commercial level.

References:

1. Jing Zhang, Lulu Ren, Daijun Zhang, Jianing Li, Peili Lu, 2019, Reduction of NO to N2 in an autotrophic up-flow bioreactor with sponge iron bed based Fe(II)EDTA complexation, Fuel, Volume 254, 15 October 2019, Article 115631.
2. Xuhui Sun, Kexin Zu, He Liang, Lin Sun, Virender K. Sharma, 2018, Electrochemical synthesis of ferrate(VI) using sponge iron anode and oxidative transformations of antibiotic and pesticide, Journal of Hazardous Materials, Volume 344, 15 February 2018, Pages 1155-1164.
3. Venkata Ramanaiah, Shabina Khanam, 2018, Modified approach of total site integration for energy conservation: A case study of sponge iron cluster, Chemical Engineering Research and Design, Volume 133, May 2018, Pages 142-154.

4. Gajendra K. Gaurav, Shabina Khanam, 2017, Profitability analysis of power generation using waste heat of sponge iron process, Energy, Volume 141, 15 December 2017, Pages 333-347.
5. Zhao, H., Cao, Y., Liu, C. and Qi, X. (2018), "A thermodynamic performance analysis on influence parameters of COG-CCHP based on exergy", World Journal of Engineering, Vol. 15 No. 6, pp. 771-785.
6. Haider, S. and Mishra, P.P. (2019), "Benchmarking energy use of iron and steel industry: a data envelopment analysis", Benchmarking: An International Journal, Vol. 26 No. 4, pp. 1314-1335.
7. Sarkar, S., Mohapatra, S. and Pattanayak, S. (2018), "Achieving success in the Digital Equalizer Program through project management", Emerald Emerging Markets Case Studies, Vol. 8 No. 2.
8. Vikas, V. and Bansal, R. (2019), "Efficiency evaluation of Indian oil and gas sector: data envelopment analysis", International Journal of Emerging Markets, Vol. 14 No. 2, pp. 362-378.
9. Hanafi, M., Wibisono, D., Mangkusubroto, K., Siallagan, M. and Badriyah, M.J.K. (2019), "Designing smelter industry investment competitiveness policy in Indonesia through system dynamics model", Journal of Science and Technology Policy Management, Vol. 10 No. 3, pp. 617-641.
10. Nishant R. Dey, Anil K. Prasad, Shravan K. Singh, 2015, Energy survey of the coal based sponge iron industry, Case Studies in Thermal Engineering, Volume 6, September 2015, Pages 1-15.
11. Mitra Debnath, R. and Sebastian, V.J. (2014), "Efficiency in the Indian iron and steel industry – an application of data envelopment analysis", Journal of Advances in Management Research, Vol. 11 No. 1, pp. 4-19.