MODELLING OF THE SUPERSONIC JET LENGTH FOR KT OXYGEN LANCE WITH 15CM DIAMETER AND 1:1 RATIO OF O2: NG AT ELECTRIC ARC FURNACE USING COMPUTATIONAL FLUID DYNAMICS (CFD)

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DECLARATION

I declare that this thesis entitled **"MODELLING OF THE SUPERSONIC JET LENGTH FOR KT OXYGEN LANCE WITH 15CM DIAMETER AND 1:1 RATIO OF O2: NG AT ELECTRIC ARC FURNACE USING COMPUTATIONAL FLUID DYNAMICS (CFD)**" is the result of my own research except as cited in references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree."

Signature	:……………………………………….
Name of Candidate	: Mohd Khairul Bin Ya'kub
Date	: April 18th , 2006

DEDICATION

Special Dedication to my beloved parents, sister and fiancée (Shuhaida Safar) for their love and encouragement.

And,

Special Thanks to supervisor (Ms Aini), my fellow course mate and all faculty members. For all of your Care, Support and Best Wishes.

Sincerely,
Mohd Khairul Bin Ya'kub

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ABSTRAK

Satu kajian telah dijalankan untuk mengoptimumkan penembak oksigen di dalam relau elektrik di PERWAJA STEEL Kemaman, Terengganu. Disebabkan oleh permintaan besi yang semakin meningkat dan kenaikan harga besi di pasaran dunia, PERWAJA STEEL mula meningkatkan pengeluaran mereka untuk mengambil peluang harga besi yang tinggi di pasaran dunia sekaligus meningkatkan pengeluaran mereka. Walau bagaimanapun, terdapat satu masalah kepada syarikat–syarikat ini, di mana mereka mendapati kos pengeluaran besi masa kini sangat mahal disebabkan kenaikan harga tariff elektrik dan juga fasiliti. Pengeluaran besi menggunakan jumlah tenaga elektrik yang sangat besar. Dengan itu, kos pengeluaran besi sangat tinggi. Menyedari masalah ini, pihak PERWAJA telah bekerjasama dengan Universiti Malaysia Pahang untuk mencari penyelesaian terbaik. Cara yang paling berkesan untuk mengatasi masalah ini adalah dengan menggunakan perisian CFD. Metode ini sangat berkesan dan menjimatkan berbanding dengan eksperiment yang terlalu mahal. Dengan mengoptimumkan penembak oksigen, tenaga kimia akan digunakan secara effisien dan penggunaan tenaga elektrik dapat dikurangkan kualiti besi juga dapat ditingkatkan. Dengan ini kos pengeluaran akan berkurang dan keuntungan akan meningkat.

ABSTRACT

A researched is conducted to study on optimization of supersonic jet lance at electric arc furnace for PERWAJA STEEL Kemaman, Terengganu. Due to the increasing of world steel demand, PERWAJA start to increase their steel production to grab the chance to increase their profit. However, there is one major problem for these companies; the current production cost of steel is too high due to increasing of energy and facilities in the world. Production of steel required a large amount of electrical energy usage. Thus, will increased the operation cost. Due to this problem, PERWAJA STEEL has doing cooperation with Universiti Malaysia Pahang to find the best solution. The most reliable way to solve the problem is by using modelling and simulation of KT oxygen lance using CFD softwre. This method is very efficient and cost saving compare to the expensive of experimental method. Optimization of oxygen lance will increased the chemical energy, reduce FeO that decreased the steelbar quality and this will decreased the electrical energy usage. Thus, the cost of production is decreased and the profit is increased.

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LIST OF SYMBOLS

γ	-	Specific heat ratio of a gas
σ	-	Surface tension
α	-	Angle of the jet
β	-	Transport coefficient
χ	-	Proportional kinetic constant for bath
ξ	-	Concentration of moles of the specie i
ρ steel	-	Density of the liquid steel
ρ ambient	-	Density of the medium where the jet flows
Lp	-	Coherence length
Mj	-	Mach number during the iso-entropic expansion of the injected gas
m	-	Number of moles
P	-	Pressure
Q	-	Gas flow rate
P throat	-	Pressure at the smallest section of the nozzle
H steel	-	Vertical depth in the bath calculated at a certain abscissa(m)
g	-	Gravity acceleration
E	-	Energy
A	-	Transversal section of the nozzle
T	-	Absolute temperature
Tj	-	Absolute temperature of the injected gas during the iso-entropic expansion within the nozzle
U t	-	Average velocity of steel in correspondence of the jet surface(m/s)
Vo	-	Velocity of the flow at nozzle outlet

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CHAPTER 1

INTRODUCTION

1.1 Steelmaking in Malaysia

Steel production has made progressive recovery since the financial crisis of 1997-98. Crude steel production has risen for the period 2000-2006 by an average of 8 % per year from almost 3.7 million mt in 2000 to 5.8 million mt in 2006. Apart from a recovery in the economy, output has since been boosted by Megasteel's hot-rolled mill, which started production in 2000. In 2005, however, crude steel production registered a decline (year-on-year) owing to a slowdown in domestic demand. However, production of HR coils increased considerably, thus resulting in positive growth of crude steel in 2006.

Like crude steel, the production of finished steel underwent a similar growth during the 2000-2006 periods, from 5.7 million mt in 2000 to 7.7 million mt in 2006. Growth in finished steel production declined in 2005, however, owing to a slowdown in domestic demand [1].

Today, Malaysia has 6.14 million mt of rolling capacity for long products. The figure is lower than the 6.68 million mt in 2000 due to the shutting down of several re-rollers and rationalization of capacities by some mills. The existing capacity for rolled-longs is more than sufficient for Malaysia's domestic requirement as the consumption of longs stood at 3.72 million mt in 2006. Some quantities of longs are also exported now. The production of rolled flats on the other hand, has increased sharply from 1999 due mainly to the installation of Malaysia's first hot-rolled coil plant with a 2.5 million mt capacity. Production has since grown from 231,000 mt in 1999, to 1.0 million mt in 2002 through to a hefty 1.92 million mt in 2006 [2].

Plate production has been strong since 2004, owing to a boost in output by Jikang Dimensi. Production has also been supported by rising demand from export markets. Production of downstream flat products, like GI and PP sheets, pipes and tubes, although improved, has been a little erratic due to material sourcing problems and fluctuating market conditions [3].

Overall, capacity utilization for the steel industry increased from a low of 35% in 1998 to 50% in 2000, improving to 63% in 2004. In 2006, utilization decreased slightly to 61%. The utilization rate of DRI/HBI declined from a high of 88% in 2004 to 77% in 2006 due to lower production arising from technical problems in the both plants [4].

In 2006, utilization of capacity of upstream long products remained healthy, with billets accounting for 74% utilization (2004:78%) and rolled longs (bars, wire rods and sections) 57% (2004:57%) [5]. The slightly lower utilization rate for longs can be attributed to slower domestic market conditions as the construction sector registered negative growth in 2005 and 2006. With the exception of hot-rolled coils, utilization in the flats sector remained low in 2006 due to installation of capacities not yet utilized, especially for plates and cold rolled coils.

1.2 Steel Demand in Malaysia

Malaysia's demand for steel products grew strongly in the 1980s, in tandem with its industrialisation efforts. While local production of long products has been somewhat sufficient to cater to the requirements of the construction sector, the country's flat product requirements were fully imported until 1998. Shortfalls in bars and wire rods were also imported to supplement local production.

A large proportion of steel imports were flat products (HR and CR sheets and coils, plates, coated sheets and seamless pipes and tubes), which were not produced locally. These items are typically used for finishing processes in industries such as shipbuilding, automotive, machinery and engineering, container making and food canning.

Imports of flats surged in 1999, prior to an import ban on such products following the commencement of Megasteel's hot-rolled plant. Megasteel was accorded protection at a time when international prices for flats were at a 20-year low. Many companies imported large quantities of flat products in anticipation of higher domestic prices. As a result, imports of hot-rolled products surged to 1.5 million mt, a situation that did not reflect the real consumption pattern of flats. Imports of hot-rolled products (including stainless steel quantities) stabilized in subsequent years, falling from 832,000 mt in 2000 to 739,000 mt in 2001 and to 663,000 mt in 2004. In 2006, imports of HR recorded 624,000 mt, including stainless steel [6].

In 2004, total steel imports amounted to 5.7 million mt (2002: 5.4 million mt). Rolled longs contributed 608,000 mt to the total import in 2004, with heavy/medium sections alone contributing 57% to this quantity. Imports of billets also increased as the Government temporarily lifted the import restriction on billets and bars in the same year.

In 2006, imports recorded 5.1 million mt, lower than in 2004 and 2005, and this could be attributed to slower demand for steel products as well as import restrictions of flat products. As a whole, there were lesser imports of billets and sections. Billets were also harder to source during recent times owing to high prices arising from export restrictions placed by China and steel bar rolling mills had been affected by this.

As for flat products, imports in 2006 were still dominated by HR and CR coils, which registered 624,000 mt and 808,000 mt respectively. There were also imports of other materials not available in Malaysia like black plates, stainless steel, cold–rolled electrical sheets and electro-galvanized sheets. Imports of stainless steel hot rolled and cold rolled coils have also increased since 2005 as a company in Johore has established a trading hub for the ASEAN region. Imports and exports of stainless steel flat products are expected to remain active henceforth.

1.3 Steel Production in Malaysia

In the past, with the exception of several downstream products, Malaysian steel products were hardly exported. This is because the steel industry is primarily domestic-oriented and consumption was strong until the mid-1990s as industrialisation progressed and infrastructure projects were aplenty.

But domestic demand plunged drastically following the 1997-98 financial crisis. As a consequence, more and more Malaysian steel makers were forced to explore opportunities for their products in export markets.

In 1998, Malaysia exported 376,000 mt of rolled longs and 320,000 mt of rolled flats Exports continued to do well in 1999 as steel mills export 269,000 mt of bars and 173,000 mt of wire rods. Downstream flat products like metallic coated steel sheets, GI sheets, pipes and tubes were also exported [7].

From 2000 onwards, exports of steel products began to moderate following a recovery in the economy and a surge in domestic consumption. But by 2004, Malaysia once again maintained its export position due largely to strong external demand elsewhere, particularly from the ASEAN region. In 2006, Malaysian exports totalled 3.3 million tons, with hot rolled coils contributing 22% of the exports.

Exports of rolled long products registered 407,000 mt in 2006, lower than the 450, 000 mt in 2005 and the 427,000 mt in 2004. This was probably due to competition from Chinese export to the ASEAN markets [8].

Billet exports however declined quite severely in 2006, recording only 250,000 mt compared to 621,000 mt in 2005 or 724,000 mt in 2004. The decline can be attributed to lower production in Perwaja due to plant maintenance issues.

1.4 Objective

1. To study on the 15mm of KT Oxygen lance diameter and the effect to the supersonic jet length at electric arc furnace using CFD modeling.
2. To study on the oxygen and natural gas ratio effect to the supersonic jet length at electric arc furnace using CFD modeling.
3. To study the range of coherent length of main oxygen KT oxygen lance.

1.5 Scope of Research Work

Optimization of the supersonic jet length is done by exploiting several parameter include pressure, flowrate and velocity of the KT Oxygen lance with ratio of 1:1 of O2:NG and 15 cm diameter of KT Oxygen lance are held constant during the study in order to determine the best parameter in this study.

1.6 Thesis Layout

Thesis layout is emphasizing the chapter in this research. There are generally four main chapters.

In chapter 2, will cover topics on steel making process, details of EAF, chemical reaction, and detailed on KT injector.

In chapter 3, methodology of this research is included First step is to model the KT injector using GAMBIT. After that, transfer this model to FLUENT, where a more detailed on process flow, temperature in all parameter, pressure and also the oxygen / hydrogen velocity in KT injector will included in the model. We then test the model by tuning the oxygen flow rate. Next, review the coke injection pattern and after that adjustment will be made on NG/O2 ratio of shrouding gas mixture.

Chapter 4, focused on the result and discussion. The developed model will be compared with the result from literature review. If the result is valid with the literature and the optimization process is succeed, that mean our research is correct but if there are different value or result, that mean there are some mistake that we had done in this research. According to that, we must correct it and find out what is the mistake that we had done.

Chapter 5 includes conclusion and recommendation. In this chapter, conclude all the various review and finding area in this work. Recommendation must stated in this research that can give more accurate result, less mistake in modeling injector using GAMBIT and FLUENT, and others step that can make result of this research accurate.

CHAPTER 2

LITERATURE REVIEW

2.1 Electric Arc Furnace

An electric arc furnace (EAF) is a furnace that heats charged material by means of an electric arc. Arc furnaces range in size from small units of approximately one ton capacity (used in foundries for producing cast iron products) up to about 400 ton units used for secondary steelmaking. Arc furnaces used in research laboratories and by dentists may have a capacity of only a few dozen grams. Temperatures inside an electric arc furnace can rise to 1,800 degrees Celsius [12].

An electric arc furnace used for steelmaking consists of a refractory-lined vessel, usually water-cooled in larger sizes, covered with a retractable roof, and through which one or more graphite electrodes enter the furnace. The furnace is primarily split into three sections: the shell, which consists of the sidewalls and lower steel 'bowl'; the hearth, which consists of the refractory that lines the lower bowl; and the roof, which may be refractory-lined or water-cooled, and can be shaped as a section of a sphere, or as a frustum (conical section). The roof also supports the refractory delta in its centre, through which one or more graphite electrodes enter.

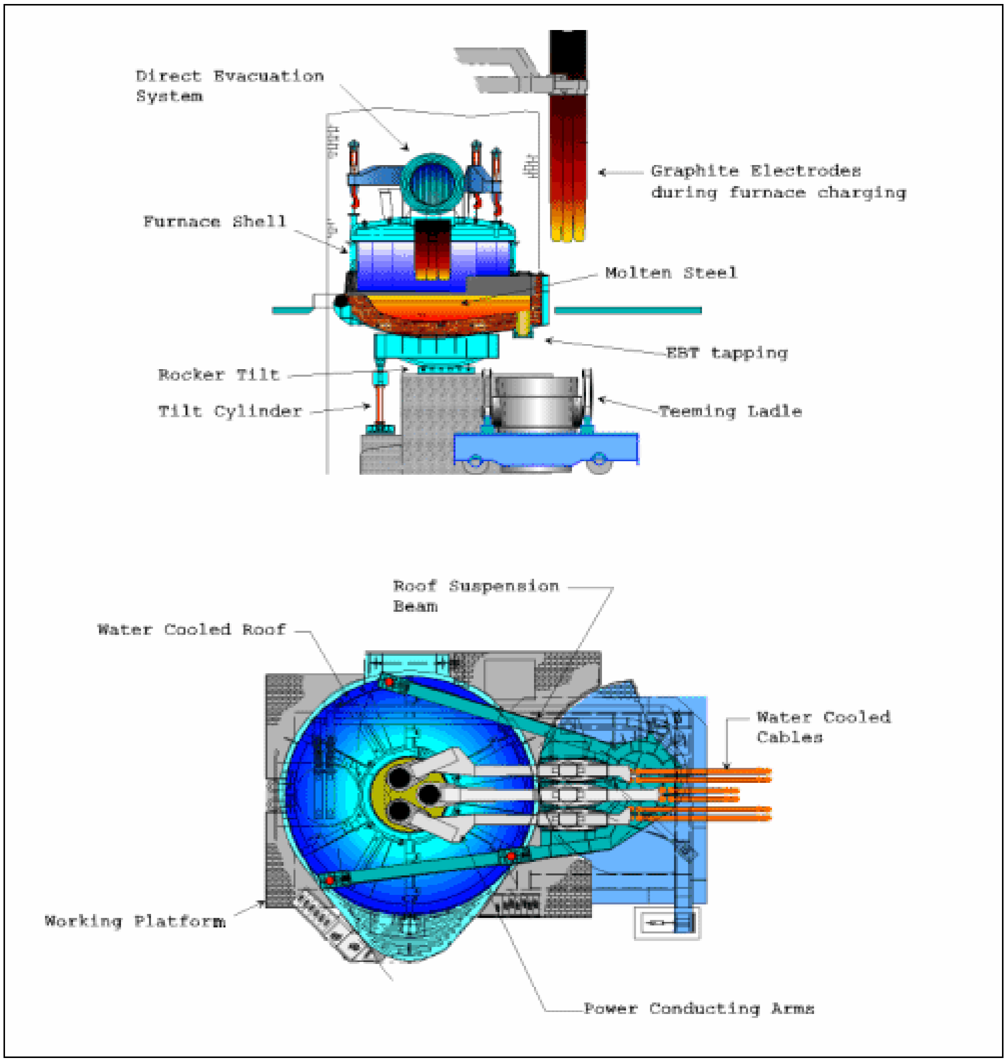

Figure 2.1: Diagram of Electric Arc Furnace

In modern meltshops, the furnace is often raised off the ground floor, so that ladles and slag pots can easily be maneuvered under either end of the furnace. Separate to the furnace structure is the electrode support and electrical system, and the tilting platform on which the furnace rests. Two configurations are possible: the electrode supports and the roof tilt with the furnace, or are fixed to the raised platform.

A typical alternating current furnace has three electrodes. Electrodes are round in section, and typically in segments with threaded couplings, so that as the electrodes wear, new segments can be added. The arc forms between the charged material and the electrode, and the charge is heated both by current passing through the charge and by the radiant energy evolved by the arc. The electrodes are automatically raised and lowered by a positioning system, which may use either electric winch hoists or hydraulic cylinders [13]. The regulating system maintains an approximately constant current and power input during the melting of the charge, even though scrap may move under the electrodes while it melts.

A mid-sized modern steelmaking furnace would have a transformer rated about 60,000,000 volt-amperes (60 MVA), with a secondary voltage between 400 and 900 volts and a secondary current in excess of 44,000 amperes. In a modern shop such a furnace would be expected to produce a quantity of 80 metric tonnes of liquid steel in approximately 60 minutes from charging with cold scrap to tapping the furnace. In comparison, basic oxygen furnaces can have a capacity of 150-300 tonnes per batch, or 'heat', and can produce a heat in 30-40 minutes [14]. Enormous variations exist in furnace design details and operations, depending on the end product and local conditions, as well as ongoing research to improve furnace efficiency - the largest furnace (in terms of tapping weight and transformer rating) is in Turkey, with a tap weight of 350 metric tonnes and a transformer of 350 MVA.

To produce a ton of steel in an electric arc furnace requires on the close order of 400 kilowatt-hours per short ton of electrical energy, or about 440kWh per metric tonne; the theoretical minimum amount of energy required to melt a tonne of scrap steel is 300kWh (melting point 1520°C/2768°F) [15]. Electric arc steelmaking is only economical where there is a plentiful supply of electric power, with a well-developed electrical grid.

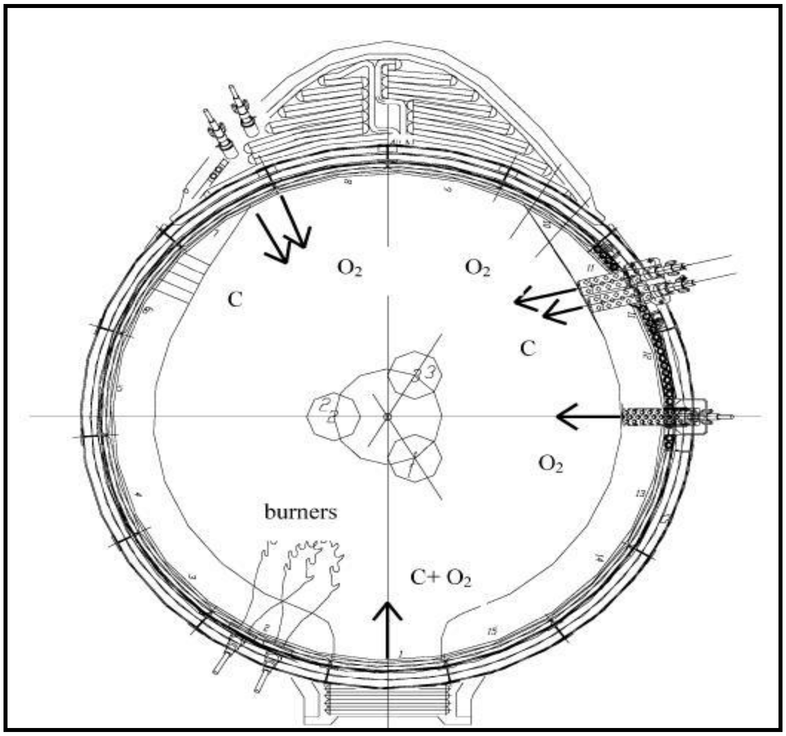

Figure 2.2: Schematic diagram of Electric Arc furnaces

Figure 2.3: Electric Arc Furnace at PERWAJA