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- **International Journal of Advanced Manufacturing Technology** (There is a prior understanding to consider the best conference papers for submission to IJAMT, but the papers will need to conform to the format stipulated and go through the regular review process of the journal by the Editors. IJAMT is an SCI journal, ranked Q2, with IF: 1.779)
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ICAMT 2015

JOHOR BAHRU, MALAYSIA, 20 -22 SEPTEMBER

4TH INTERNATIONAL CONFERENCE ON ADVANCED MANUFACTURING TECHNOLOGY

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31 August 2015

Prof. Hasan Bassri,
Faculty of Mechanical Engineering,
University of Sriwijaya,
Indonesia

Dear Authors,

ACCEPTANCE AND INVITATION LETTER

Firstly, thank you for your submission to the 4th International Conference on Advanced Manufacturing Technology (ICAMT 2015) to be held in Johor Bahru, Malaysia on 20 - 22 September 2015. We would like to inform that initial screening and review is in favor of your submission.

ID : 097
Authors : Hasan Basri, Irsyadi Yani
Title : Fatigue Analysis Of Rotary Cement Kiln Welded Using

On behalf of the Committee, we are pleased to notify the conditional acceptance of your submission to ICAMT 2015. Accordingly, we also invite you present the work during ICAMT 2015.

To proceed, you are kindly asked to register and arrange for presentation of your work in ICAMT 2015. Other arrangements regarding the conference will be informed through you or updated through the website. Should you have any inquiry, please contact us through email: info@icamt.net

Congratulations for the acceptance of your submission and looking forward to see you in Johor Bahru, Malaysia for ICAMT 2015.

Best wishes,

Izman Sudin
Chair, ICAMT 2015

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4th International Conference on

Advanced Manufacturing Technology

(ICAMT2015)

Johor Bahru, Malaysia

20 – 22 September 2015

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Edited by Denni Kurniawan and Fethma M. Nor

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11:10 - 11:30	Atul Saraf Dr. Babasaheb Ambedkar Technological University	046 Ultrasonic Assisted Photochemical Machining (UAPCM) of SS316L
11:30 - 11:50	Zazuli Mohid Universiti Tun Hussein Onn Malaysia	062 Machining Performance of Laser Assisted Micro Milling (LAμM) on Ti6Al4V
11:50 - 12:10	Hainol Akbar bin Hj. Zaman Polytechnic Sultan Azlan Shah	070 Machinability of Co-28Cr-6Mo Cobalt Chromium Molybdenum Alloy during High Speed End Milling at Different Cutting Speed using Uncoated and Coated Carbide Tools
12:10 - 12:30	Dr. Amrifan S Mohruni Sriwijaya University	075 Hard Turning Investigation on Surface Roughness Using Cubic Boron Nitride (CBN) Insert
12:30 - 12:50	Dr. Mohamed Konneh International Islamic University Malaysia	116 Experimental Investigation Of The Effect Of Cutting Tool Coating on Delamination During Milling Metal Matrix Composite (MMC)
Materials Properties and Treatments **Time: 10:30 - 12:50 - Banquet Hall (Front)**		
10:30 - 10:50	Y. C. Wee Universiti Teknologi Malaysia	027 Influence of Microstructure Evaluation to Damping Properties of Cu-Al-Ni Shape Memory Alloys
10:50 - 11:10	R Lullus LG Hidajat Sebelas Maret University	028 New quaternion-based bending model for spring mass system applied in cloth drapes simulation
11:10 - 11:30	Ayad Omran Abdalla Universiti Teknologi Malaysia	074 Effect of Heat Treatment Parameters on the microstructural changes in Ti-6Al-4V Alloy
11:30 - 11:50	Fakhrina Fahma Sebelas Maret University	076 The Effect of Variable Drying Mechanism of Indirect Passive Solar Dryer
11:50 - 12:10	Dr. Supakit Rooppakhun Suranaree University of Technology	085 The Strength Analysis of a Bus Superstructure based on the Accuracy Improvement of T-Junction Joint Stiffness
12:10 - 12:30	Prof. Hasan Basri Sriwijaya University	097 Fatigue Analysis of Rotary Cement Kiln Welded Using Finite Element Method

ID097: Fatigue Analysis of Rotary Cement Kiln Welded Using Finite Element Method

Hasan Basri[1], Irsyadi Yani[1]*

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Abstract

In this research, the implementation of Shell of Kiln problem have been discussed. The results obtained in this research are taken based on the simulation and experimental work. This chapter discusses only the simulation work. The simulation works are performed to evaluate the fatigue of the shell of kiln. To validate the characteristic of fatigue problem simulation, the mechanical and thermal load are implemented on the shell of kiln. The results are analysed in detail in this chapter for fatigue life for shell of kiln. In this work, shell of kiln has been modelling by solid works and fast2014. All the boundary conditions (mechanical load, thermal load, Young's modulus, density, etc.) must be evaluated such as the actual condition. This simulation shown how the most relevant aspects of the developed work presented in this report can contribute to the state-of-the-art of the analysis fatigue life of Rotary Cement Kiln technique with innovative ideas and strategies. It also reviews if the obtained results achieve the proposed objectives. The main goal of the work presented in this research is to propose fatigue life analysis algorithm in shell of kiln using finite element analysis. Due to the dimensionality of the problem addressed, the research specification has to set limits to the applicability of the research by selecting only mechanical load problems in rotary cement kiln tasks; and goal-seeking, to predict the fatigue life simulation investigated. From simulation, model and boundary conditions are defined. Crack growth behaviour in rotary kiln was predicted. As the crack grows, the speed of crack depth increase.

Keywords: FEA, Fatigue Analysis, Rotary Kiln, crack simulation.

Fatigue Analysis of Rotary Cement Kiln Welded Using Finite Element Method

Hasan Basri[1]*, Irsyadi Yani[1]

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Abstract

In this research, the implementation of Shell of Kiln problem have been discussed. The results obtained in this research are taken based on the simulation and experimental work. This chapter discusses only the simulation work. The simulation works are performed to evaluate the fatigue of the shell of kiln. To validate the characteristic of fatigue problem simulation, the mechanical and thermal load are implemented on the shell of kiln. The results are analysed in detail in this chapter for fatigue life for shell of kiln. In this work, shell of kiln has been modelling by solid works and fast2014. All the boundary conditions (mechanical load, thermal load, Young's modulus, density, etc.) must be evaluated such as the actual condition. This simulation shown how the most relevant aspects of the developed work presented in this report can contribute to the state-of-the-art of the analysis fatigue life of Rotary Cement Kiln technique with innovative ideas and strategies. It also reviews if the obtained results achieve the proposed objectives. The main goal of the work presented in this research is to propose fatigue life analysis algorithm in shell of kiln using finite element analysis. Due to the dimensionality of the problem addressed, the research specification has to set limits to the applicability of the research by selecting only mechanical load problems in rotary cement kiln tasks; and goal-seeking, to predict the fatigue life simulation investigated. From simulation, model and boundary conditions are defined. Crack growth behaviour in rotary kiln was predicted. As the crack grows, the speed of crack depth increase.

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1. INTRODUCTION

A kiln is basically an industrial oven, and although the term is generic, several quite distinctive designs have been used over the years, such a kiln in PT. Semen Baturaja made about 1,200.000 tonnes of clinker per year. Rotary kiln shell is a large scale welded structure with 4.5 m in diameter and 75 m in length, and produced by welding thin cylindrical steel plate one by one.

Padded plates are directly soldered to the shell in the supporting rollers places to reduce their concentrated stress. Crack are often initiated at these welded joints, and the over long circumferential crack are prevailing at welded joints near the supporting rollers.

However, Kikuchi et.al, (2010) has predicted of two interacting surface cracks of dissimilar sizes by finite element analysis. The simulations were performed for fatigue crack growth experiments and the method validity was shown on this research. It was shown that the offset distance and the relative size were both important parameters to determine the interaction between two surfaces of crack; the smaller crack stopped growing when the difference in size was large. It was possible to judge whether the effect of interaction should be considered based on the correlation between the relative spacing and relative size. In 2014, Fatigue crack growth simulation in heterogeneous material using finite element method has generated by Kikuchi et.al. Kikuchi have developed a fully automatic fatigue crack growth simulation system using FEM and applied it to three-dimensional surface crack problems, in order to evaluate the interaction of multiple surface cracks, and the crack closure effects of surface cracks. The system is modified to manage residual stress field problems, and the stress corrosion cracking process is simulated.

To prediction of crack propagation under thermal, residual stress fields using S-Version FEM (S-FEM), Kikuchi was employed to solve a crack growth problem by combining with the auto-meshing technique, this re-meshing process of the local mesh becomes very simple, and modelling of three-dimensional crack shape becomes computationally easy. On the other hand, in 2004, Irsyadi has develoved visualization of finite element analysis in 3D (C, C++, under Linux/Fedora), with this system, analysis for extra large problems such as fatigue life predictions becomes easy and fastly. Irsyadi, Kikuchi, and Kanto employed numerical analysis of 3-D Surface Crack in 2006, and then, Irsyadi and Kikuchi was developed a numerical analysis in the low carbon steel by finite element method and experimental method under fatigue loading. In this research they were predicted fatigue live of material under stresses.

The prediction of fatigue life of rotary cement kiln welded shell is not completely understood and fascinating, therefor it should be investigated. For rotary kiln shell, cracks can grow with complex over loading conditions for over thousands of tons, and then results in premature shell failure. The effecting conditions crack growth include material characteristics, initial crack size, service stresses, and stress concentration due to over heated in hot spot area, all these conditions are random. Fatigue life of the welded shell during crack growth need to be predicted numerically by using finite element analysis and experimentally. In relation to the problems above, we propose the research topic of fatigue life analysis of rotary cement kiln welded shell (case study in P.T. Semen Baturaja).

The general objective of the fatigue life analysis attempts to provide the answers to general questions, which remain unclear on the evolution of the crack growth and its impacts on failure in rotary cement kiln system. In addition, the research is intended to bring our knowledge of the simulation and experimental of the fatigue life analysis in the welded joins of rotary cement kiln in PT. Semen Baturaja.

The primary objective of this study is to investigate the fatigue life of the crack growth analysis in the welded joins of rotary cement kiln in PT. Semen Baturaja. We approach the goal through a combined analysis of fatigue growth observational data and numerical model simulation.

2. RESEARCH METHOD

The main geometrical characteristics of the rotary kiln shell is shown in Table 1.

Table 1: The main geometrical characteristics of the rotary kiln

Magnitude	Value	Units
Cold real length	75	Meters
Inner diameter	4.5	Meters
Number of tyres	3	--
Slope	3.5	%

The thicknesses of the shells along the different sections of the rotary kiln are given in Table 2. In Table 2 zero is placed in the upper end of the rotary kiln, called 'inlet-I'. The distances between supports, in millimeters, are given in Table 3 where 'III-outlet' denotes the lower end of the rotary kiln.

Table 2: Thicknesses of the shells along the different sections of the rotary kiln

Section (mm)	Thickness (mm)	Section (mm)	Thickness (mm)
0–10,300	25	42,900–45,100	60
10,300–11,900	40	45,100–46,900	40
11,900–14,100	60	46,900–65,300	28
14,100–19,700	40	65,300–66,900	40
19,700–41,100	28	66,900–69,500	70
41,100–42,900	40	69,500–72,500	90
		72,500–75,000	60

Table 3: Distances between supports [8,22].

Supports	Distance (mm)
inlet–I	13,000
I–II	31,000
II–III	27,000
III–outlet	4,000

Shown in Tables 2, 3 and Fig. 1 is the rotary kiln (1) along with the structural elements to rotate the kilns (3), (12), (8), and (16) around its longitudinal axis. The kiln (1) includes an elongated, cylindrical, rotating shell (13) which has a feed end (9), an opposite discharge end (6), a burner pipe (4). The kiln (1) is erected so that the discharge end (6) is at a lower level then the feed end (9) in order to cause the material (15) being processed. It travels through the open processing zone to the discharge end (6). The kiln shell (13) is supported by riding rings or tyres (3) that engage steel rollers (12) which are supported on concrete piers (5) and steel frames (7).

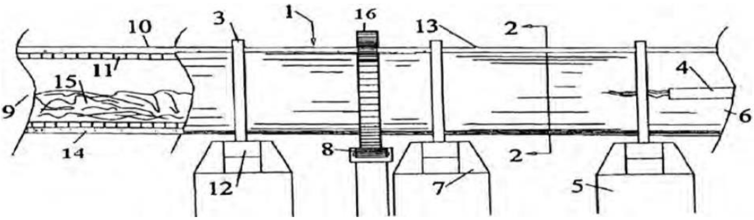


Fig.1. Thicknesses of the shells along the different sections of the rotary kiln

Materials used for the kiln are shown in Table 4. These materials are used to build the kiln components. The shell, tyre, roller and pinion are the main components in the kiln. However, the material has been modeled as isotropic and linear, elastic temperature dependent, according to the elastic properties of the steel used in Table 4.

Table 4: Materials are used for the kiln.

Componnent	Material
Shells	ASTM 526 Grade 70 or SS 400
Tyres Cast iron	GS-25 Mo.25
Rollers Cast iron	GS-42 Cr Mo.5
Pinion	30 Cr Ni Mo 8 (ISO R 638 = II-68 Type 3)

As mentioned earlier there are mainly four methods to predict fatigue of welded components:

- Nominal Stress
- Structural Stress
- Effective Notch Stress
- Linear Elastic Fracture Mechanics (LEFM)

The effects of welding residual stresses, R-ratio, wall thickness and improvement techniques are included in this research collaboration. In case of variable amplitude loading, Palmgren-Miner´s linear damage rule is used when the design methods nominal, structural and effective notch stress are applied.

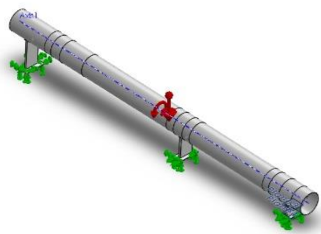
3. EXPERIMENTAL RESULTS AND DISCUSSIONS

The results obtained in this research are taken based on the simulation and experimental work. This chapter discusses only the simulation work. The simulation works are performed to evaluate the fatigue of the shell of kiln. To validate the characteristic of fatigue problem simulation, the mechanical and thermal load are implemented on the shell of kiln. The results are analysed in detail in this chapter for fatigue life for shell of kiln.

In this work, shell of kiln has been modelling by Autodesk Inventor2014. All the boundary conditions (mechanical load, thermal load, Young's modulus, density, etc) must be evaluated such as the actual condition. In first year, the simulation of the shell of kiln only conducted is conducted to determine the fatigue life of the shell of kiln.

The development of modelling is the initial work that marks the natural condition of the designed software into the simulation plafform. In this phase all algorithms of simulation condition are implemented using a standard Finite Element Analysis. Within this development model, the architecture is validated and the main functions and algorithms are tested. During the design, by using Static Analysis has been implemented in the shell of kiln as shown in Figure to achieve robust performance, high reliability and minimal computational cost.

Model Information



Model name: kilngbrplvvvvv
Current Configuration: Default

Solid Bodies

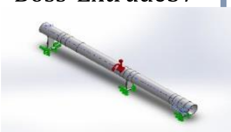
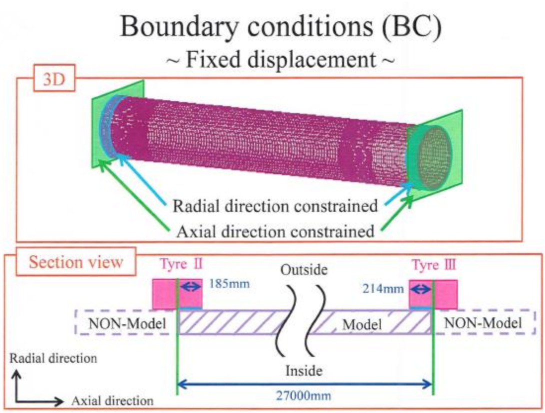
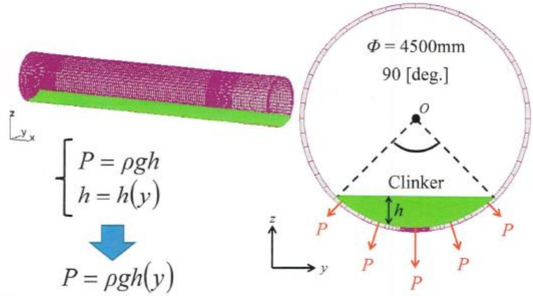
Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Boss-Extrude57 	Solid Body	Mass:1692.34 kg Volume:0.215585 m^3 Density:7850 kg/m^3 Weight:16584.9 N	E:\project\KILN\kilngbrplvvvvv.SLDPRT Aug 30 22:56:16 2014

Figure Model of Shell of Kiln



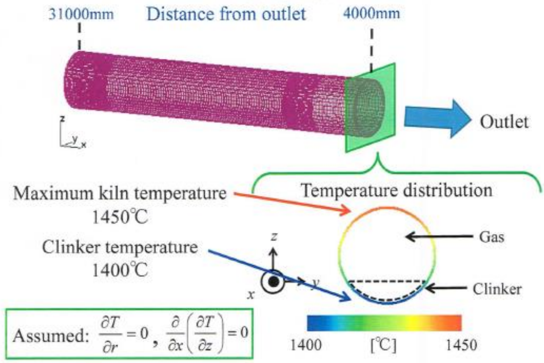
Boundary conditions (BC)

~ Concentrated force ~

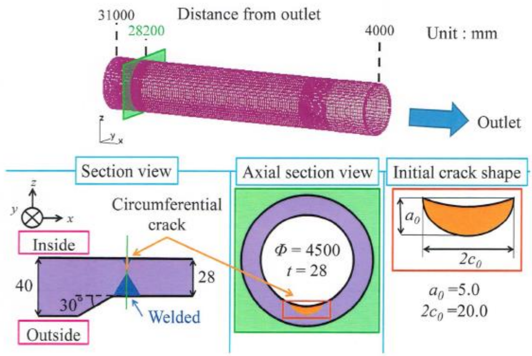


Boundary conditions (BC)

~ Thermal ~

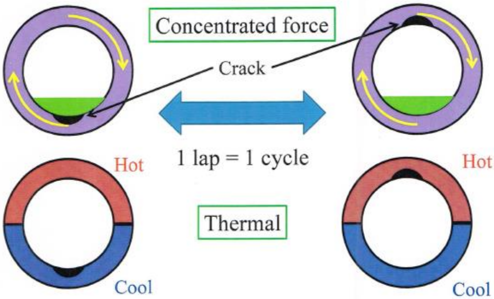


Initial crack

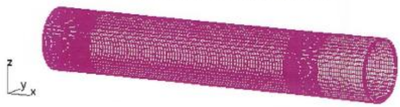


Boundary conditions (BC)

~ Cycle ~



Material constants



Young's modulus	E	206	[GPa]
Poisson's ratio	υ	0.3	[-]
Linear expansion coefficient	α	1.17×10^{-5}	[℃$^{-1}$]
Paris's law constant C	C	4.99×10^{-12}	[-]
Paris's law constant n	n	3.20	[-]
density Clinker	ρ	3150	[kg/m^3]

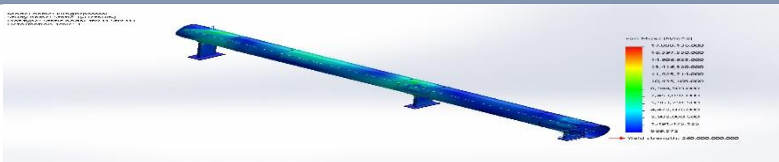
$$\varepsilon = \alpha \Delta T \ , \quad \frac{da}{dN} = C(\Delta K)^n$$

Under static analysis, stress and deformation in the kiln obtained as shown below. From the simulation results are known critical areas that occur in the kiln. Obtained from the static value, subsequent fatigue analysis can be performed.

The calculated loads and stresses were used to perform a low cycle fatigue evaluation using the actual operating data. The operating temperatures were lower than the temperatures anticipated in the design specifications. There were no known cycles corresponding to the anticipated 450°C gas inlet temperature upset condition, and only three cycles to the normal operating temperature. Hence, the actual operating cycles were used to evaluate the fatigue damage.

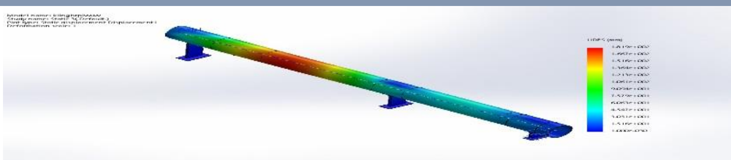
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	869.572 N/m^2 Node: 3498	1.78881e+007 N/m^2 Node: 61802



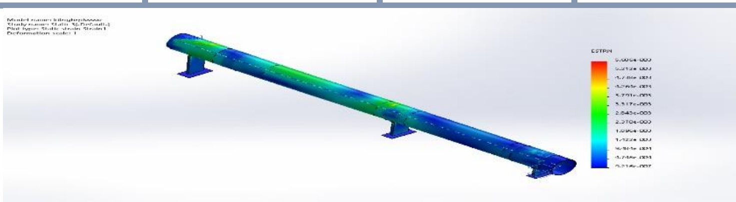
kilngbrplvvvvv-Static 3-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 3068	181.886 mm Node: 24131



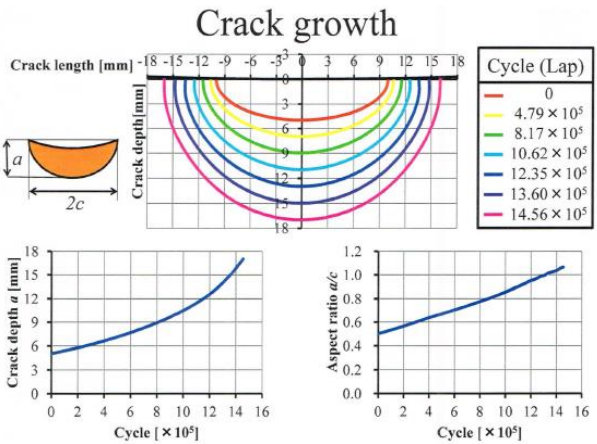
kilngbrplvvvvv-Static 3-Displacement-Displacement1

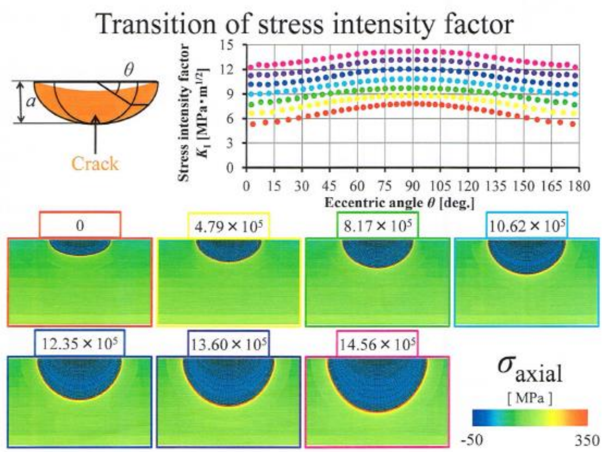
Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	9.21557e-007 Element: 1805	0.00568555 Element: 30857



kilngbrplvvvvv-Static 3-Strain-Strain1

Since local stresses were far in excess of the yield strength of the materials at the stitch welds, elastic-plastic analyses were used to obtain the strain ranges needed to perform a low cycle fatigue evaluation. The evaluation was made using fatigue design curves obtained by applying a factor of cycles to the theoretical failure curves. Based on the design curves, a cumulative fatigue usage had been reached when failure occurred. This is consistent with the knowledge that cracks had initiated and grown to a critical size and propagated as fast fractures at this usage. Actual failure occured between the design fatigue curve and the theoretical mean failure data for small polished laboratory test specimens. Failure below the mean laboratory failure curve is expected due to size effects, surface finish effects, environmental effects and scatter in the data.





The results of the structural analyses of the original design showed that the flexibility of the weight stresses and reduced thermal bending stresses in the duct. Hence, bending of the duct imposed high cyclic loads and stresses on the support truss, buckling several truss members. With properly designed duct supports. Bending of the duct does not bend the supporting truss. Moreover, the flexibility of the truss would have no effect on dead weight stresses in the duct. This is important since the typical design sequence involves first designing the duct, and then using the resulting weight to design the truss.

4. CONCLUSIONS

This research shows how the most relevant aspects of the developed work presented in this report can contribute to the state-of-the-art of the analysis fatigue life of Rotary Cement Kiln technique with innovative ideas and strategies. It also reviews if the obtained results achieve the proposed objectives.

The main goal of the work presented in this research is to propose fatigue life analysis algorithm in shell of kiln using finite element analysis. Due to the dimensionality of the problem addressed, the research specification has to set limits to the applicability of the research by selecting only mechanical load problems in rotary

cement kiln tasks; and goal-seeking, to predict the fatigue life simulation investigated.
From simulation, model and boundary conditions are defined. Crack growth behaviour in rotary kiln was predicted. As the crack grows, the speed of crack depth increase.

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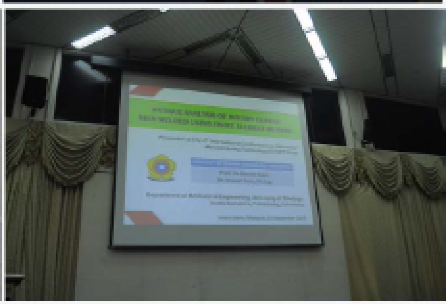


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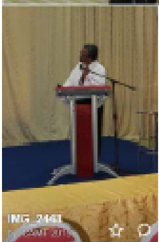
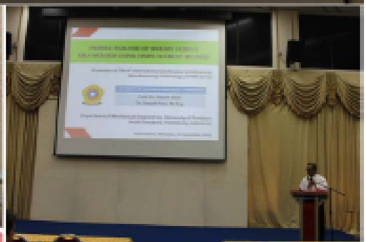
Johor Bahru, Malaysia, 20 September 2015



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