The Sriwijaya International Conference on Engineering, Science & Technology (SICEST2016) in Bangka Island-Indonesia, 9-10 November 2016.

SICEST

SRIWIJAYA INTERNATIONAL CONFERENCE ON ENGINEERING, SCIENCE & TECHNOLOGY (SICEST2016)
Bangka Island – Indonesia, 9-10 November, 2016

- PAPER ACCEPTANCE NOTIFICATION -

First Author	:	**Hasan Basri**
Affiliation	:	Faculty of Engineering, University of Sriwijaya, Indonesia
Co-Author(s)	:	Akbar Teguh Prakoso
Paper Title	:	VIBRATION ANALYSIS OF ROTARY CEMENT KILN USING FINITE ELEMENT METHOD
Submission No	:	274 **Paper ID : MCI-015**

Dear Hasan Basri,

Based on recommendations of the reviewers and the technical program committees, we are pleased to inform you that your paper identified above has been **accepted** for **oral presentation** and **selected for publication (in one of SICEST publications indexed** by **SCOPUS)**. Hence, you are cordially invited to present the paper at **Sriwijaya International Conference on Engineering, Science and Technology** (SICEST) 2016, which will be held on Bangka Island Indonesia, November 09-10, 2016.

Herewith, the steps you must take as soon after receiving this acceptance letter.
1.Fill and complete the **Online Registration Form** (provided on SICEST website)
2.Receiving invoice document from the committee
3.Finish the payment of registration fee via bank transfer
4.Send a payment confirmation by e-mail to sicest@ft.unsri.ac.id
Please complete the registration steps above before October 10, 2016.

After completing the registration and payment, you will be informed about the review result and the designated publication. A revision and paper template adjustment will be further requested according to the selected journal or proceedings.

Please direct all questions pertaining to registration, conference program and paper publication with an e-mail message to: sicest@unsri.ac.id.

Again, congratulations and we are looking forward to see you at the conference in Bangka Island, Indonesia.

Sincerely

Dr. Leily Nurul Komariah
Conference & Publication Manager

organized by
Faculty of Engineering Sriwijaya University
Srijaya Negara Street Palembang-Indonesia
Phone/Facs. +62711360286, +62 81258102150
http://sicest.ft.unsri.ac.id

SICEST

SRIWIJAYA INTERNATIONAL CONFERENCE ON
ENGINEERING, SCIENCE & TECHNOLOGY (SICEST2016)
Bangka Island – Indonesia, 9-10 November, 2016

CONFERENCE FEE INVOICE

Registration No	:	cpf-13361
Participation Category	:	Oral Presenter (Lecturer/Researcher)
Participant Name	:	**Hasan Basri**
Affiliation	:	Mechanical Engineering, Sriwijaya University
e-mail	:	hasanbas1960@gmail.com
Phone No	:	
Paper ID	:	**MCI-015**

Description	Qty	Currency	Fee
Registration for Paper Presenter (Lecturer/Researcher)	1	IDR	2,000,000
Publication Fee	1	IDR	1,250,000
Additional Paper	0	IDR	0
Others		IDR	0
Total amount due		IDR	**3,250,000**

- The registration and publication fee must be paid **only through the bank transfer (cash not acceptable).**
- All registration and publication fees should be paid in advance in IDR or US$ to; Bank Account : **KONSORSIUM PUI ENERGI-SICEST** – Account Number : 0464220086 (Bank BNI), Swift Code : BNINIDJAXXX
- All bank charges and commissions must be paid by the participants. Please inform your bank about this when ordering the transfer.
- Send the payment proof (scanned document) by e-mail to sicest@unsri.ac.id attn to : Ms. Marwani Zachrie

organized by
Faculty of Engineering Sriwijaya University
Srijaya Negara Street Palembang-Indonesia
Phone/Facs. +62711360286, +62 81258102150
http://sicest.ft.unsri.ac.id

Plenary Session

SICEST 2016 PLENARY SESSION A			
time	Tanjung Kelayang Ballroom I, Wednesday, November 9, 2016		
07.00-08.00	**REGISTRATION**		
08.15-08.20	**OPENING REMARKS**	BY SYMPOSIUM CHAIRMAN/DEAN	
08.20-08.40	*PLENARY SESSION 1*	**KEYNOTE SPEAKER**	**PROF. ANIS SAGGAFF [INDONESIA]**
08.40-09.00		INVITED TALK 1	DR. NURLY GOFFAR [SINGAPORE]
09.00-09.20		INVITED TALK 2	DR. ISMAIL SAID [MALAYSIA]
09.20-09.40		INVITED TALK 3	DR. M. SEDDIK MEDDAH [OMAN]
09.40-09.50	MOMENTO & PHOTO SESSION		
09.50-10.10	COFFEEBREAK		

SICEST 2016 PLENARY SESSION B			
time	Tanjung Kelayang Ballroom II , Wednesday, November 9, 2016		
07.00-08.00	**REGISTRATION**		
08.10-08.15	**OPENING REMARKS**	BY SYMPOSIUM CHAIRMAN/DEAN	
08.15-08.50	*PLENARY SESSION 1*	**KEYNOTE SPEAKER**	PROF. AHMAD FAUZI ISMAIL (MALAYSIA)
08.50-09.20		**KEYNOTE SPEAKER**	PROF. OSMAN ADIGUZEL (TURKEY)
09.20-09.25	MOMENTO & PHOTO SESSION		
09.25-09.40	COFFEEBREAK		
09.40-09.55	*PLENARY SESSION 2*	INVITED TALK 1	DR. SURYADI ISMADJI (INDONESIA)
09.55-10.10		INVITED TALK 2	DR. VICTOR SONG (KOREA)
10.10-10.25		INIVTED TALK 3	PROF. YI HSU JU (TAIWAN)
10.25-10.30	***MOMENTO & PHOTO SESSION***		

1

SYMPOSIUM PRESENTATION SCHEDULE

5

SYMPOSIUM C - ROOM 4 - Wangka 5 (1st FLOOR)							
SRIWIJAYA INTERNATIONAL SYMPOSIUM ON MECHANICAL, INDUSTRIAL AND MATERIAL ENGINEERING							
TIME			**PAPER-ID**	**TITLE**	**AUTHOR**	**AFFILIATION**	
15.45-17.45	SESSION 3 (PARALEL)	1	MCI-003	Cutting Condition of Coated Carbide when Hard Turning of Steel under Dry Cutting	Armansyah Ginting Ginting, Aqqil Limianto, Kevin Tan and Putra Chandra Wijaya	Laboratory of Machining Processes, Department of Mechanical Engineering, Faculty of Engineering, Universitas Sumatera Utara, Medan	
		2	MCI-028	Tandem Bike Design for Apartment Residents as an Idea to Reduce Air Pollution	Bambang Iskandriawan, Jatmiko, Eri Naharani Ustazah and Firman Hawari	Department of Industrial Design, Faculty of Civil Engineering and Planning, Institut Teknologi Sepuluh Nopember, Surabaya	
		3	MCI-019	Numerical Analysis of Shell and Tube Heat Exchangers with Segmental and Helical Baffle	Sri Poernomo Sari,Andi Cahya Ichi, Astuti	Mechanical Engineering Department, Faculty of Industrial Technology, Gunadarma University, Jakarta	
		4	MCI-021	Redesigning a High Wheel Bicycle: A Case Study of Inventive Problem Solving	Risdiyono	Department of Mechanical Engineering Islamic University of Indonesia, Yogyakarta	
		5	MCI-013	Experimental study on a Hybrid Loop Heat Pipe	Iwan Setyawan, Imansyah Ibnu Hakim and Nandy Putra	Mechanical Engineering Department, Faculty of Engineering, Universitas Indonesia, Depok	
		6	MCI-015	Vibration Analysis Of Rotary Cement Kiln Using Finite Element Method	Hasan Basri and Akbar Teguh.	Mechanical Engineering Department, Faculty of Engineering, Sriwijaya University, Palembang	
		7	MCI-016	Influences of Pitch-Length Louvered Strip Insert on Thermal Characteristic in Concentric Pipe Heat Exchanger	Indri Yaningsih and Agung Tri Wijayanta	Mechanical Engineering Department, Faculty of Engineering, Sebelas Maret University, Surakarta	
		8	MCI-030	Development Of An Automatic Sorting System	Hassan Basri, M A Hannan and Irsyadi Yani	Mechanical Engineering, Faculty of Engineering, Sriwijaya University, Indonesia	
		9	MCI-029	Analysis of Effect of Capture Fisheries Policy to the Supply Chain of Fish Canning Industry using System Dynamic Modeling	Ratna Purwaningsih and Buna Rizal	Industrial Engineering Department, Engineering Faculty, Diponegoro University, 50275, Indonesia	

27

SICEST

- REVIEW REPORT -

SRIWIJAYA INTERNATIONAL CONFERENCE ON ENGINEERING, SCIENCE & TECHNOLOGY (SICEST2016)

Bangka Island – Indonesia, 9-10 November, 2016

PAPER ID	:	**MCI-016** **SUBMISSION NO : 274**
Paper Title	:	VIBRATION ANALYSIS OF ROTARY CEMENT KILN USING FINITE ELEMENT METHOD

	Poor	Fair	Good	Very Good	Excellent
Abstract Quality			√		
Introduction			√		
Methodology				√	
Result & Discussion			√		
Comments	Reviewer#1			Reviewer #2	
	(ABSTRACT) The goal and method of this research is not describe clearly (INTRODUCTION) - review on previous related work/papers should be available so that the readers will easily find the original contribution of this paper. (RESULTS AND DISCUSSIONS) Please re-write and Focused on the conclusion.			(INTRODUCTION) Please give the explanation more details of the novelty of this research (RESULTS AND DISCUSSIONS) Discussion results of experiments should be elaborated more deeply (OVERALL EVALUATION) This paper present a good topic and well prepared It can be accepted for publication in international journal	
Revision	❑ Major	☑ Minor		❑ No revision	
Decision	☑ Accepted		❑ Not Accepted		
Publication Recommendation [indexed by **SCOPUS**]					

organized by
Faculty of Engineering Sriwijaya University
Srijaya Negara Street Palembang-Indonesia
Phone/Facs. +62711360286, +62 81258102150 http://sicest.ft.unsri.ac.id

VIBRATION ANALYSIS OF ROTARY CEMENT KILN USING FINITE ELEMENT METHOD

Hasan Basri[1,*], Irsyadi Yani[1], Akbar Teguh Prakoso[1]

[1] Department of Mechanical Engineering, Faculty of Engineering, University of Sriwijaya, Indonesia, *hasan_basri@unsri.ac.id

Abstract: In this research, the implementation of shell of kiln problem has been discussed. The results obtained in this research are taken based on the simulation and experimental work. This research discusses only the simulation work that are performed to evaluate the fatigue of the shell of a kiln. To validate the characteristic of fatigue problem simulation, the mechanical and thermal load are implemented on the shell of a kiln. The results are analyzed in detail in this research for fatigue life for the shell of a kiln. In this work, the shell of the kiln has been modeled by Solid Works and Fast 2014. All the boundary conditions (mechanical load, thermal load, Young's modulus, density) must be evaluated such as the actual condition. This simulation showed how the most relevant aspects of the developed work presented in this paper can contribute to the state-of-the-art of the analysis of fatigue life of rotary cement kiln technique with innovative ideas and strategies. It also reviews that the obtained results achieve the proposed objectives. The dynamics of the large scale rotary machine with multiple wheel bearing structures is investigated in this research. Based on the Finite Element Method, the transfer matrices and overall transfer equation are developed to calculate natural frequencies, and response overall motion equation is established for response analysis. The main goal of the work presented in this research is to propose vibration analysis and fatigue life analysis algorithm in the shell of a kiln using finite element method. 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 the simulation, model and boundary conditions are defined. Crack growth behavior in the rotary kiln was predicted. As the crack grows, the speed of crack depth increase.

Keywords: FEA, vibration analysis, rotary kiln

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 circumferencial 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 FEA. 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 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.

The 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 modeling of three-dimensional crack shape becomes computationally easy. On the other hand, in 2004, Irsyadi has developed 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 life of material under stresses.

The prediction of fatigue life of rotary cement kiln welded shell is not completely understood, therefore it should be investigated. For rotary kiln shell where the vibration occurs with high displacement, cracks can grow with a complex overloading conditions for over thousands of tons, and then

*Correspondence to: Hasan Basri, Department of Mechanical Engineering, Faculty of Engineering, University of Sriwijaya, Jalan Palembang Prabumulih KM.32, Ogan Ilir, Sumatera Selatan, Indonesia. Tel: +62 711 580272

E-mail Address: hasan_basri@unsri.ac.id

results in premature shell failure. The affecting conditions crack growth include material characteristics, initial crack size, service stresses, and stress concentration due to overheated in hot spot area, all these conditions are random. The 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 vibration analysis and fatigue life analysis of rotary cement kiln (case study in PT. Semen Baturaja).

The primary objective of this study is to investigate the area of vibration with high displacement and fatigue life of the crack growth analysis in a rotary cement kiln in PT. Semen Baturaja.

2. Research Method

This research has the overall goal of identifying the characteristics of crack growth that determine fatigue life and hence the risk posed to rotary cement kiln (welded shell). To accomplish this goal, this collaboration research brings together a multi-disciplinary team with expertise in Tribology, Fracture Mechanics, Computational Mechanics and Smart Engineering. It includes two research projects: 1). Dynamic modeling and analysis of the large-scale rotary machine with multi supporting; and 2). Fatigue life of rotary kiln, along with supporting cores.

Separate report follow for each of the projects. In each section, we discuss: a). the research performed and results generated in this year, and b). the challenges encountered in the research and proposed actions.

Research Project 1: Dynamic modeling and analysis of the large-scale rotary machine with multi supporting.

The analysis of dynamic modeling of the kiln shell is shown in Fig. 1 and Fig. 2.

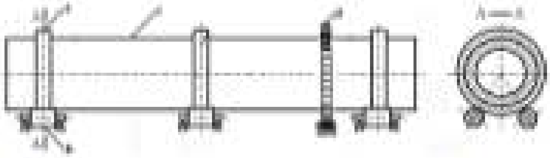
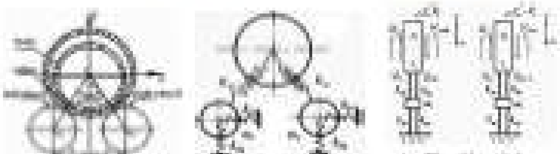


Fig. 1. The sketch of the large-scale rotary machine with multi-supporting. (a: tyre, b: roller, c: body, d: kiln drive)



(a) Geometry Model (b) Mechanic model (c) The Sketch in y and z plane

Fig.2. The geometry and mechanic model of wheel bearing supporting structure.

Data Input:

Mass of rotary kiln shell = 55.92 ton.
The weight of rotary kiln shell = 54,86 x 10^4 N

The data of mass, material the rotary kiln and the boundary conditions are shown in Fig. 3, Table 1 and Fig. 4 respectively.

Fig 3. Mass of rotary kiln shell is calculated by Autodesk 2016

Table 1. Material of a kiln shell

No	Specification of ASTM 516 Grade 70	Value
1.	Tensile strength	485 MPa
2.	Yield strength	260 MPa
3.	Density	7.85 g/cm^3
4.	Poisson ratio	0.29
5.	Modulus of elasticity	200 GPa

Boundary Conditions:

1. Type of analysis: Natural Frequency with (modal) load stiffening.
2. Clinker weight is neglected.
3. Speed of rotary kiln = 3.5 rpm.
4. Ambient temperature = 37°C.
5. The kiln shell inclination (deviation) = 3.5°
6. Rotation Axis be based on the position of kiln drive
   X = - 57149. 77 mm
   Y = 29605.84 mm
   Z = 27150. 75 mm

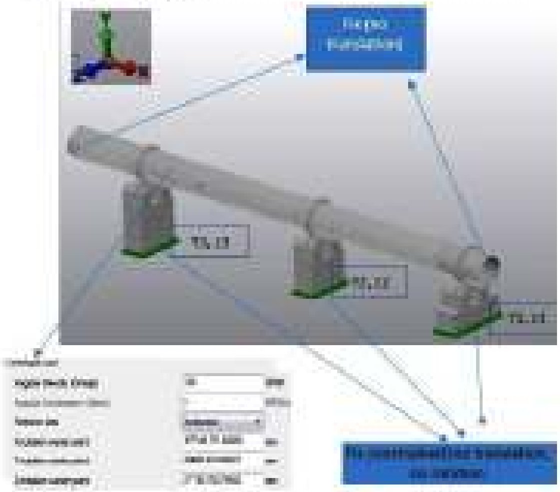


Fig. 4. Boundary Conditions

3. Results and Discussion

We computed the natural frequencies of the body system of a rotary kiln, as well as the response with axis line deflection of the supporting structure. The rotary kiln is shown in Fig 1. The body length and radius are 75 m and 4.5 m respectively, the total weight is 54,86 x 10^4 N. The kiln has 3 supporting structures, located 4 m, 31 m, and 62 m from kiln head respectively. The kiln shell is divided into various elements according to body structure as shown in Fig. 1 (b: roller). Any subsystem is composed of rigid disks, elastic shafts, and linear springs.

Anisotropy stiffness of the supporting structures in y and z directions are given as follows (see Fig. 5);

Direction	K Value
Y	K_{yy1} = 6.5 x 10^4 N/mm, K_{yy2} = 36 x 10^4 N/mm, K_{yy3} = 39.08 x 10^4 N/mm
Z	K_{zz1} = 3.76 x 10^4 N/mm, K_{zz2} = 20.78 x 10^4 N/mm, K_{zz3} = 20.56 x 10^4 N/mm

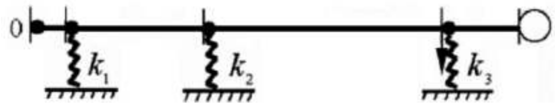


Fig. 5. The sketch of rotary kiln and dynamics model of the body system.

Table 2. Order of natural frequencies of a kiln shell. β_k (for k=1, 2, 3, ... 150)

Number of frequency	Circular frequency (rad/sec)	Frequency (Hertz)	Priode (sec)
1	1136600	180900	552,80
2	1157100	184160	543,01
3	1756500	279550	357,71
4	1785700	284200	351,86
5	1814300	288760	346,31
...	...	...	...
143	15188000	2417200	41,37
144	15284000	2432500	41,11
145	15429000	2455700	40,72
146	15453000	2459400	40,66
147	15566000	2477400	40,36
148	15642000	2489500	40,17
149	15673000	2494400	40,09
150	**15715000**	**2501100**	**39,98**

Natural Frequencies of the rotary kiln.

The results of the natural frequencies β_k (k = 1, 2, 3, ... 150) of the body system are shown in Table 2. Displacement value at first of 150 number of frequencies are shown in Fig. 6, Fig.7 and Fig. 8. It can be seen clearly from Table 2 that the results of natural frequencies obtained by FEM are shown in Fig 9.

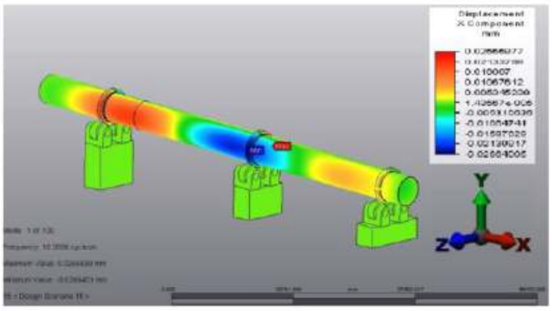


Fig. 6. Displacement at first of 150 number of frequencies along x-axis

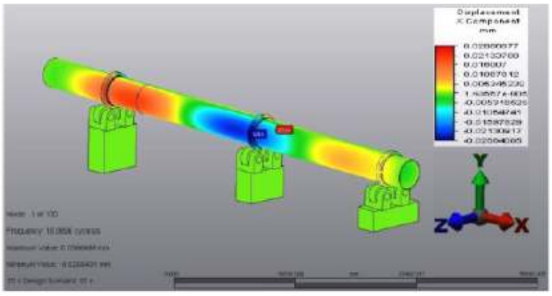


Fig. 7. Displacement at first of 150 number of frequencies along y-axis

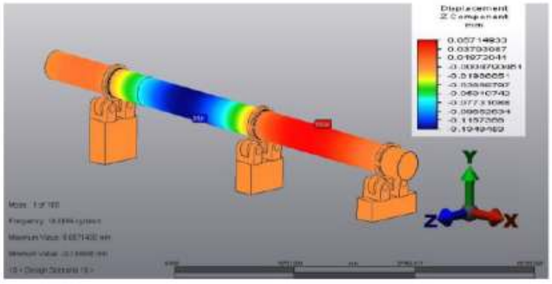
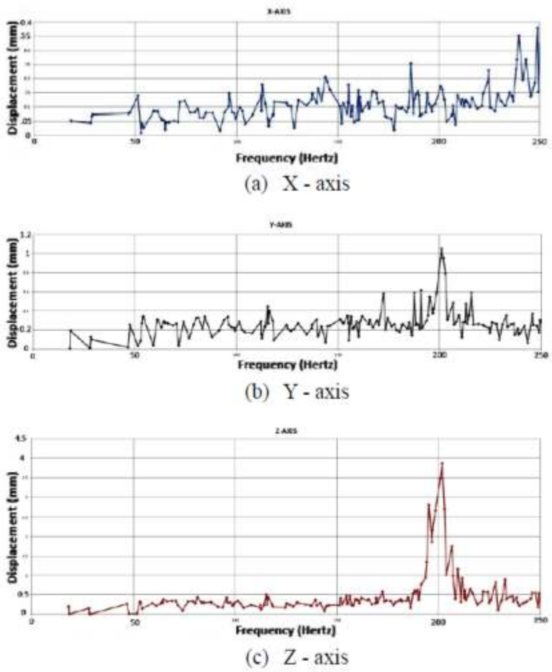


Fig. 8. Displacement at first of 150 number of frequencies along Z-axis



(a) X - axis

(b) Y - axis

(c) Z - axis

Fig. 9. The results of natural frequencies by FEM

3

Research Project 2: Fatigue life of rotary kiln along with supporting cores.

Considering a finite element analysis, characteristics of a kiln shell are a pretension and a mating part contact. The pretension can generally be modeled with static loading, thermal deformation, a constraint equation, or an initial strain. For a thermal deformation method, the pretension is generated by assigning virtual different temperatures and thermal expansion coefficients to the shell, clinker and temperature of gases. In this work, in order to generate a finite element model for the kiln shell with clinker and temperature of gases, two kinds of models are introduced. All the proposed models are taken into account above primary characteristics such as a pretension effect and a contact behavior between shell, clinker and temperature of gases. The prediction of the crack propagation are considered on crack emanating from contact surface between kiln shell and clinker and welded joint on the kiln shell surface. On this finite element model, the final mesh consisted of 40,856 elements and 45,245 nodes. Based on vibration analysis and thermal analysis, the elements along the direction of crack advance had a length of 13-23 m and 22-24 m respectively. Following the stress and deformation simulation, fatigue crack growth was modelled by repeated loading (mass of clinker and thermal gases), unloading, advancing the crack and then the loading again.

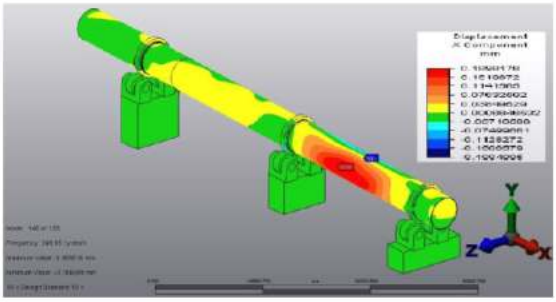


Fig. 10. Location of fatigue of a rotary kiln

4. Conclusion

The dynamics of the large scale rotary machine with multiple wheel bearing structures is investigated in this research. Based on the finite element method, the transfer matrices and overall transfer equation are developed to calculate natural frequencies, and response overall motion equation is established for response analysis.

Structures are simplified as linear springs, and their anisotropy equivalent stiffness are deduced. Taken a rotary kiln as an instance, natural frequencies, modal curves, and response vibration are obtained. The body vibration modal curves illustrate the cause of dynamical errors in common axis line measurement methods. The displacement response can be used for further measurement dynamical error analysis and compensation. The response overall motion equation could be applied to predict the body motion under abnormal mechanics condition, and provide theory guidance for machine failure diagnosis.

The main goal of the work presented in this research is to propose fatigue life analysis algorithm in the shell of a 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 the simulation, model and boundary conditions are defined. Crack growth behavior in rotary kiln was predicted. As the crack grows, the speed of the crack depth increase

References

[1] ABP, ASME boiler and pressure vessel code II - material properties. The American Society of Mechanical Engineers, 1995.

[2] ABP, ASME boiler and pressure vessel code VIII division 2 - alternative rules, Appendix 5. Design based on fatigue analysis, 1995.

[3] Basri, H., "Numerical Solution of Fatigue Stress in Journal Bearing", Proceeding of 5th International Conference on Numerical Analysis in Engineering (NAE 2007), University of Sumatera Utara (IC-STAR USU), ISSN: 979-96139-6-7, pp. 8.1-8.7, 2007.

[4] Chandra, H., Basri, H., "Analisis Fatigue Poros Pompa Vakum", (in Indonesian), Prosiding Seminar Nasional Sains dan Teknologi 2007, Lembaga Penelitian, Universitas Lampung, Bandar Lampung, 27-28 Agustus 2007.

[5] Cement kiln, http://en.wikipedia.org/wiki/Talk, 2010.

[6] Coz Díaz JJ, Mazón FR, García Nieto PJ, Suárez Domínguez FJ. Design and finite element analysis of a wet cycle cement rotary kiln. Finite Elements in Analysis and Design; 39(1):17–42, 2002.

[7] Energy Efficiency Component EU-China. A reference book for the industry. Beijing, 2009.

[8] Frederic O., The kiln book: materials, specifications and construction. Chilton Book Company, 1997.

[9] Irsyadi Yani, Visualization of Finite Element Analysis in 3D (C, C++, Under Linux/Fedora), Seminar PPI Jepang Tengah, Toyohashi University of Technology, Japan.

[10] Irsyadi Yani, Masanori Kikuchi, "Numerical Analysis in the Low Carbon Steel by Finite Element and Experimental Method under Fatigue Loading", Proceeding of The 5th International Conference on Numerical Analysis in Engineering (NAE), 2007.

[11] Irsyadi Yani, Masanori Kikuchi, Yasuhiro Kanto, "Numerical Analysis of 3-D Surface Crack", International Conference of Computational Mechanics and Numerical Analysis, 2006.

[12] Irsyadi Yani "Analysis K-Value on the crack pipe under Torsion" Jurnal Rekayasa Mesin, FT. Unsri Jurusan Teknik Mesin.

[13] Kikuchi M., Fatigue crack growth simulation in heterogeneous material using S-version FEM, International Journal of Fatigue 58, 2014.

[14] Kikuchi M., Growth prediction of two interacting surface cracks of dissimilar sizes, Engineering Fracture Mechanics 77, 3120–3131, 2010.

[15] Kikuchi M., Crack growth analysis in a weld-heat-affected zone using S-version FEM, International Journal of Pressure Vessels and Piping 90-91, 2012.

[16] Liu XY., Specht E., Temperature distribution within the moving bed of rotary kilns: measurement and analysis. Chemical Engineering and Processing. Process Intensification 2010;49(2):147–50.

[17] Merk Blatter A., Technical rules for pressure vessels. Verlag KG Carls Heymanns, 1997.

[18] Thamrin, I., Basri, H., "Exact and Numerical Solution of Pure Torsion Shaft", Proceeding of 5th International Conference on Numerical Analysis in Engineering (NAE 2007). University of Sumatera Utara (IC-STAR USU), ISSN: 979-96139-6-7, pp.3.24-3.29, 2007.

[19] Xuejun Li, Yiping Shen and Songlai Wang, "Dynamic modeling and analysis of the large scale rotary machine with multisupporting", *Hunan University of Science and Technology, Hunan Provincial Key Laboratory of Health Maintenance for Mechanical Equipment, Hunan, China, publisher Hindawi,*