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Dynamic Analysis and Streamlining Functioning of Hearth Layer Screen

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***Abstract*—The premature failure of the sinter screen rear panel is a problem faced by the Steel industry. The primary failures seen are breakage of the sinters screen plates and the crack development on the rear panel of the sinter screens. The causes of the crack formation are investigated. The modal analysis of the Hearth Layer Screen is done for finding the natural frequency of the system. The effect of the resonance under dynamic condition of the system is analyzed. The modes of vibration of the HLS were predicted by calculating the natural frequencies using discrete analysis. The results showed that, there is no effect of resonance on the crack formation on the rear panel.**

Keywords—Mode, Resonance.

I. INTRODUCTION

The sintering is one of simplest process which can be used for optimising the raw materials used for making the steel. Quality of product is one of the major requirements in production. The sintering process assures quality and less wastage of the raw materials under usage. Malan J, Barthel W, and B.A. Dippenaar [6] states that, the sintering process depends on several parameters and control of these parameters ensures good production rate and quality. The design considerations for sinter plant are pellet cars, sinter strand drive, take up mechanism, crash deck and finger crusher, ignition hood. The parameters to be controlled for the optimisation of the sintering process are percentage of water addition, percentage of coke addition, pressure drop, bed depth, ignition time, ignition temperature, hearth layer, yield, production rate and sinter fines ratio.

Jia P Zhao, Chin E Loo, and Rodney D Dukino [4] described about the combustion of coke, as a fuel in sinter mix leading to the formation of a moving flame front is a most important process in iron ore sintering. The fuel used, air flow rate through the sintering bed, the size distribution of the fuel and the exposure of fuel particles to the flowing gases all have an effect on properties of the formed flame front and combustion behaviour.

The sinter particles formed are screened for further use in blast furnace. The screening of the sinter particles into required size is accomplished by Hearth Layer Screen. The frequent failures are occurring on the Hearth Layer Screen during the screening process. Usual failures are the cracks on the screen mats and cracks on the rear panels. Goutam Mukhopadhyay, Pankhuri Sinha, and Sandip Bhattacharyya [3] states that, changing the material with required properties is a great option for decreasing the frequent failures of Hearth Layer Screen. The analysis methods done for studying the failure are plant visit, compositional analysis, microstructural examination, energy dispersive spectroscopy, measurement of hardness and impact properties.

Zhao Yue mina, Zhang Cheng yonga, Wang Yi binb, and Ren Zi tingc [8] described about the dynamic design of a Hearth Layer Screen using Finite element method. The dynamic characteristics of a Hearth Layer Screen depend on its working condition. Finite element method can help in analysing the structural characteristics and dynamic characteristics of vibrating screen, thereby dynamic modification of the structure can be done. The analysis methods adopted are modal analysis, dynamic analysis and optimization. The natural frequencies of the system were obtained using modal analysis and the dynamic response of the system was calculated. Based on the analysis the structural optimisation was done.

Chang C.M, Cheng W.T, and Huang C.E, Dul S.W [2] states that the erosion of the Hearth during tapping process in the blast furnace is a major factor to be considered for understanding the life of blast furnace. The erosion of hearth can be decreased by increasing the height of inner material layer called deadman.

The temperature inside the blast furnace is to be predicted for the stability of production of steel. Lijun Wu, Huier Cheng, Yongkang Su, and Haidong Feng [5] shows that, Finite Element Method and Boundary Element Method can be used for predicting the heat transfer in bottom and hearth of blast furnace. The numerical prediction of hearth of blast furnace can also be predicted by computational fluid dynamics. It is by generating a 3D model of Hearth layer and applying the boundary conditions. Such method has been verified by Yu Zang, Rohit Deshpande, Huang D, Pinakin Chaubal, and Chenn Q Zhou [7].

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Fatigue is one of the phenomenon causing the crack on the dynamic structures where the cyclic load applications are occurring. Bin Sun, and Zhaoxia Li [1] proposed a multi scale fatigue damage model, which can describe fatigue damage accumulation at different stress levels.

Under expansion, in stage-2 of VSP, two hearth layer sinter screens (1.65 T/m3) and two return fines screen (1.75 T/m3) for screening the sinter are supplied by M/S. TVV, Italy. The screen is of single deck linear motion screen of size 8700 mm long and 3650 mm wide. Such a big screen is first of its kind designed by the supplier. During the performance trials, rear panel of Hearth Layer Screen-1 got cracked. Similar cracks are also observed in rest of the screens. The rectification of the problem includes a detail design study of the entire screen.

II. METHODOLOGY

The aim of our work is to identify whether resonance is the phenomenon causing the failure of the rear panel of the Hearth Layer Screen as shown in Fig. 1. For that a modal analysis and transient analysis of the system were done using ANSYS Workbench 14.5.

Fig. 1. Hearth Layer Screen (VSP)

A. *Plant visit and visual observation*

Plant visit was conducted to understand the process and the nature of failure at the field. The Sinter Plant working was observed and the working of Hearth Layer Screen was also observed. It was observed that, the rear panel of the Hearth layer Screen was found to be cracked particularly at the middle were the sinter particles fall at maximum amount. The cracks were found to be propagating between the bolted joints.

B. *Modal analysis using ANSYS Workbench 14.5*

The Hearth Layer Screen model was imported into ANSYS Workbench 14.5 in .step file format. Each part of the Hearth Layer Screen is made of Structural Steel. Twenty two helical springs are supporting the Hearth Layer Screen. The springs are made of Carbon steel. The modal analysis was selected in ANSYS Workbench 14.5 and the proper engineering data is selected. The model to be analyzed was imported in .step format. The model was meshed using tetrahedral elements adopting patch conformation method. The meshed model is shown in Fig. 2.

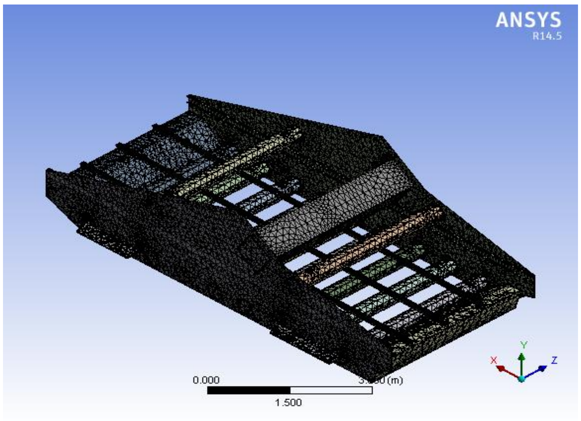

Fig. 2. Mesh generated for the modal analysis

The Boundary conditions of spring stiffness is given as equivalent stiffness of two sets of springs in the inlet side and the discharge end. The springs are represented as Lumped mass in the modal. The equivalent spring stiffness for the set of springs in the inlet side is given as 988769.5315 N/m and of the set of springs in the discharge end is 1186523.438 N/m. The lower sides of each of the springs are fixed. The 70 modes were evaluated in the modal analysis and among those, the modes up to the excitation frequency of the eccentric mass are considered. The speed of eccentric mass rotation is around 560 rpm. From the mode shapes of 70 modes, the mode shapes up to 20 modes were analyzed, since the excitation frequency was calculated as 9.33Hz.

C. *Transient structural analysis in ANSYS Workbench 14.5*

Transient Structural Analysis is a dynamic analysis in which the analysis of the Hearth Layer Screen can be done separately for each mode of natural frequency. The interference of the excitation frequency with the natural frequency can be analyzed by getting the deformations under the boundary conditions applied and by the dynamic stress evaluation.

In ANSYS Workbench 14.5, the transient structural was selected and the engineering data of structural steel and carbon steel are selected. The Hearth Layer Screen model was then imported into ANSYS Workbench 14.5 in .step file format. The boundary conditions of spring stiffness are given as, equivalent stiffness of two sets of springs in the inlet side and the discharge end. The springs are represented as Lumped mass in the model. The equivalent spring stiffness for the set of springs in the inlet side is given as 988769.5315 N/m and of the set of springs in the discharge end is 1186523.438 N/m. The lower sides of each of the springs are fixed. The Load conditions were given on the rear panel and the exciter beam. The load on the rear panel is given as vector components as shown in table I.

TABLE I. Rear panel loading condition

Force on the x axis	-600 N
Force on the y axis	-741 N
Force on the z axis	0 N

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The load on the eccentric mass is different based on the frequency of vibration induced. Four modes of frequencies are analyzed based on the nearness to the excitation frequency.

III. RESULTS

The free vibration of the system is analyzed and different modes up to 20 mode shapes were obtained as shown in table II. The excitation frequency calculated was 9.33Hz. So the modes up to the excitation frequency were considered for the analysis for evaluating the condition of resonance. Among these natural frequencies from first mode to sixth mode are nearly similar values. From seventh mode onwards variable values are obtained. The twentieth mode is near to the excitation frequency. So among these, the modes to be evaluated for checking the resonance phenomena selected are first mode, seventh mode, nineteenth mode and twentieth mode.

TABLE II. First twenty natural frequencies of the system

Mode	Frequency In Hz
1	2.5304
2	2.5312
3	2.5317
4	2.5466
5	2.5503
6	2.5508
7	6.2535
8	6.4333
9	6.9623
10	6.9637
11	6.9653
12	7.0137
13	7.0194
14	7.0213
15	7.5166
16	7.7757
17	7.976
18	7.9761
19	7.977
20	9.6337

The dynamic stress acting on the system is evaluated in this analysis. The crack formation in real system is found on the Rear panel. So the working of Hearth Layer Screen under the natural frequencies selected is to be evaluated by inducing the boundary conditions on the Hearth Layer Screen. For each mode three steps of rotation are considered for the analysis. The boundary conditions of load are applied on the rear panel as shown in table III and on the exciter beam

TABLE III. The boundary condition applied on the rear panel

Step	Force X	Force Y	Force Z
1	0	0	0
2	-600N	-741N	0
3	-600N	-741N	0
4	-600N	-741N	0

Based on the boundary conditions the transient analysis was done. The total deformation and the equivalent stress for the respective modes were obtained. The total deformation of the system under the selected modes is shown in Fig. 3, Fig. 4, Fig. 5, Fig. 6. The equivalent stress acting on the system at each modes of vibration were obtained and are shown in Fig. 7, Fig. 8, Fig. 9, Fig. 10. The maximum equivalent stresses and shear stresses are found to be on the exciter beam. The rear panel is not deforming in any of the analysis and also the equivalent stress is found to have no effect on the rear panel of the Hearth Layer Screen.

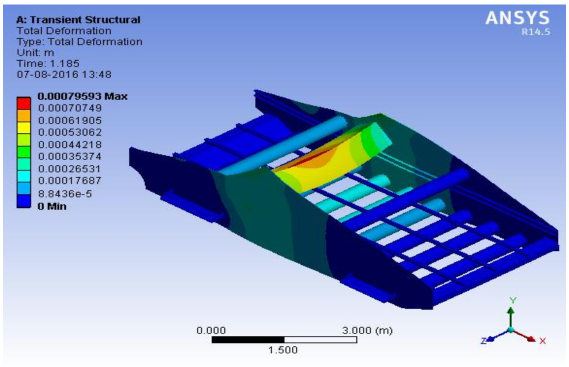

Fig. 3. Total deformation of the system in first mode

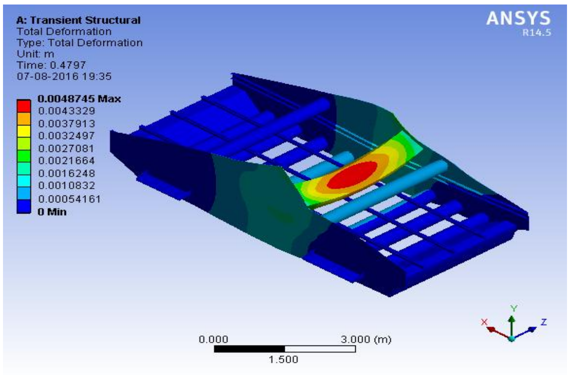

Fig. 4. Total deformation of the system in seventh mode

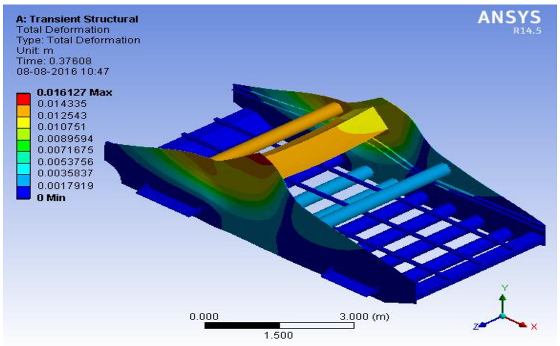

Fig. 5. Total deformation of the system in nineteenth mode

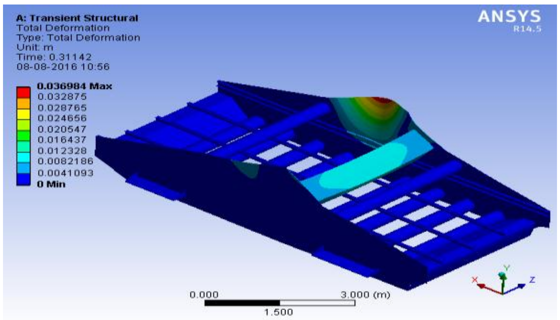

Fig. 6. Total deformation of the system in twentieth mode

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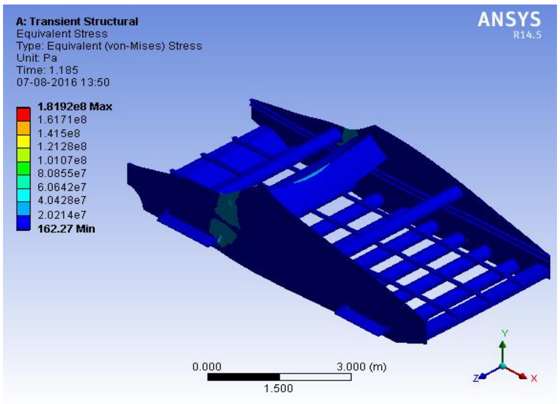

Fig. 7. Equivalent Stress of the system in first mode

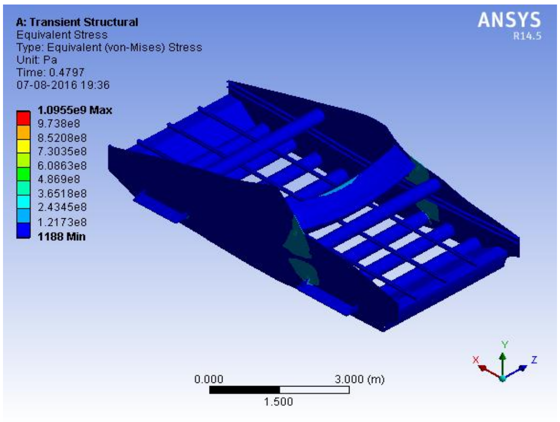

Fig. 8. Equivalent stress of the system in seventh mode

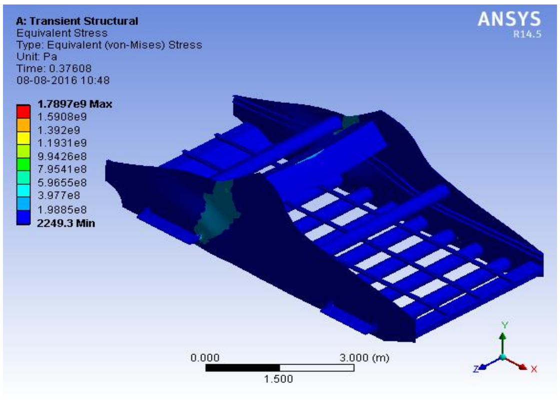

Fig. 9. Equivalent stress of the system in nineteenth mode

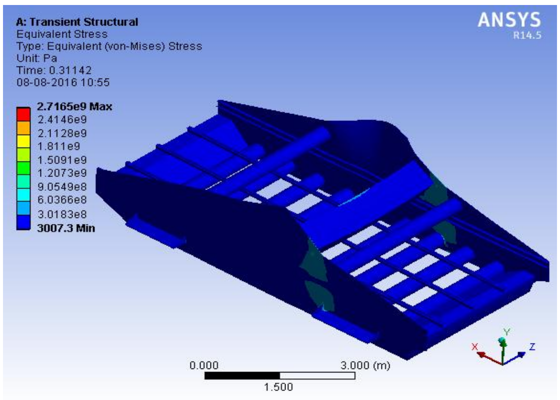

Fig. 10. Equivalent stress of the system in twentieth mode

IV. CONCLUSIONS

The study showed that the phenomena of resonance have no effect on the crack formation on the rear panel. The modal analysis using ASYS Workbench 14.5 reveals the effect of different modes of frequencies on the Hearth Layer Screen. Among the natural frequencies obtained, the frequencies which have much effect on the response of the system were analyzed. The transient analysis based on the selected natural frequencies reveals that, there is no effect of equivalent stress and shear stress on the rear panel. The total deformations at the four modes considered are affecting mostly on the exciter beam and the rear panel has much stiffness to avoid crack formation with the effect of resonance. The deformations are shown to be increasing with the increase in the natural frequency. But up to the excitation frequency calculated, no deformations are shown on the rear panel. This shows the chance that another phenomenon is causing the crack formation on the rear panel.

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