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Innovative structural solution for heavy loaded vibrating screens

Sergio Baragetti *

GITT – Centre on Innovation Management and Technology Transfer, Università degli Studi di Bergamo, via Salvecchio 19, 24129 Bergamo, Italy
Department of Management, Information and Production Engineering, Università degli Studi di Bergamo, Viale Marconi 5, 24044 Dalmine, BG, Italy

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ABSTRACT

An innovative design solution is presented in this paper; it allows the enhancement of structural resistance and the dynamic performances of a vibrating screen for inert materials. The new design does not significantly affect the geometry of the traditional screens, keeping the same global dimensions and almost the same mass value. In fact the aim of this study was to design a new vibrating screen having almost the same dimensions but that could give a much higher dynamic structural resistance at frequencies and load amplitudes much higher than the nominal ones. Numerical finite element models were generated to investigate the structural and dynamic behavior of a standard vibrating screen. These analyses allowed the modification of the geometrical parameters of the traditional screen and to design the new one. Accurate three-dimensional FE models were so generated in order to evaluate the best design solution, in terms of dynamic structural resistance, able to reduce the stress values at the most stressed area. The fatigue resistance of all the components of the new screen was checked, with particular attention to the welding joints. Experimental full scale tests on a prototype of the new screen were carried out in order to validate the numerical models and mostly to verify the structural integrity of the vibrating screen during the working conditions. Strains at the surface of the most stressed areas of the screen were measured in dynamic working conditions, at different frequencies and load amplitudes; these stress values were compared with the numerical ones in order to validate the numerical results. The new screen was patented.

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1. Introduction

Heavy loaded vibrating screens, horizontal or inclined, are mounted at the top of batch type asphalt plants or continuous asphalt plants. The screen allows the selection and segregation of prescribed components of an aggregation of pebbles and stones according to specific particle size. The accuracy of the selection is very important in a lot of applications for which reaching the correct recipe of the final mixture is mandatory. Among such applications the asphalt plants, that allow the production and installation of the asphalt for roads and highways, require a perfect dosage of all the components. A prescribed percentage of inert materials with designed particle size has to be achieved for the asphalt mixture and a good vibrating screen has to guarantee its performances for 24 h a day (Smith et al., 2001; Bringiotti, 2001).

The temperature of the inert materials that flow through the vibrating screen is in the range 150–200 °C. Pebbles and stones have to be accurately heated and dehydrated before the classification by screen in order to be ready to be put in the mixture and bond to the other constituents of the asphalt. The asphalt production plant is usually a vertical tower which can be up to 30 m high. The inert materials (pebbles and stones) have to be pre-dosed, heated and dehydrated before entering the vibrating screen at the top of the tower (they reach the top of the tower by means of a bucket elevator that feeds a drying heater). After the screening process the pebbles of different particle sizes are gathered into steel hoppers put under the screen. The material stored in the hoppers feeds the mixer according to prescribed percentage ratios; during the mixing process the bitumen is added with specified additives that allow the production of a compact texture asphalt.

Dynamic analysis of the screen has was done in order to proceed with the design of the new modified screen presented in this paper. The literature survey of the papers dealing with the study of the dynamic behavior of the screen was carried out. In (He and Liu, 2009) the authors proposed a theoretical model for the dynamic behavior evaluation of vibrating screens and a new screen with elliptical trace was presented. The multi degree of freedom vibration theory was used and no experimental validation of the model was presented. In (Zhao et al., 2009) the aim of the paper is to improve the reliability of large vibrating screens. The authors

* Address: Department of Management, Information and Production Engineering, Università degli Studi di Bergamo, Viale Marconi 5, 24044 Dalmine, BG, Italy
E-mail address: sergio.baragetti@unibg.it

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Nomenclature

A	horizontal distance between the center of gravity and the unload side spring support (m)
A'	vertical distance between the center of gravity and the unload side spring support – positive in the downward direction (m)
B	horizontal distance between the center of gravity and the load side spring (m)
B'	vertical distance between the center of gravity and the load side spring – positive in the upward direction (m)
$C = 2R/d$	spring curvature ratio
c_1	total longitudinal damping coefficient of the springs related to the unload side supports (Ns/m)
c_{t1}	total transverse damping coefficient of the springs related to the unload side supports (Ns/m)
c_2	total longitudinal damping coefficient of the springs related to the load side supports (Ns/m)
c_{t2}	total transverse damping coefficient of the springs related to the load side supports (Ns/m)
c	total longitudinal damping coefficient of the supports (Ns/m)
c_t	total transverse damping coefficient of the supports (Ns/m)
c_c	critical damping coefficient in the longitudinal direction (Ns/m)
c_{ct}	critical damping coefficient in the transverse direction (Ns/m)
d	wire diameter of the spring (m)
e	eccentricity of the direction of application of the active force with respect to the center of gravity (m)
E	longitudinal elastic modulus of the spring (MPa)
F_0	active force amplitude (N)
$F_{0,x}$	horizontal component of the active force (N)
$F_{0,y}$	vertical component of the active force (N)
F	FEM model active force amplitude (N)
F_x	FEM model horizontal component of the active force (N)
F_y	FEM model vertical component of the active force (N)
G	transversal elastic modulus of the spring (MPa)
k	single spring longitudinal stiffness (N/m)
k_t	single spring transversal stiffness (N/m)
k_1	total longitudinal stiffness of the springs related to the unload side supports (N/m)
k_{t1}	total transverse stiffness of the springs related to the unload side supports (N/m)
k_2	total longitudinal stiffness of the springs related to the load side supports (N/m)
k_{t2}	total transverse stiffness of the springs related to the load side supports (N/m)
K	total longitudinal stiffness of the supports (N/m)
K_t	total transverse stiffness of the supports (N/m)
m	global mass of the system (kg)
n	electric engines rotational speed (rpm)
R	radius of the spring helix (m)
α	inclination of the active force with respect to the vertical (°)
δ_{ST}	static displacement (mm)
θ	pitching angle of the vibrating screen (°)
J_g	global moment of inertia of the system (kg m^2)
y	vertical coordinate of the center of gravity (m)
x	horizontal coordinate of the center of gravity (m)
ω	electric engines pulsation (rad/s)
ω_D	frequency of the damped system (rad/s)
ω_F	angular frequency of the loading force (rad/s)
$\omega_N = \sqrt{K_{eq}/M}$	natural frequency of the system (rad/s)
ω_{nx}	angular frequency of the system in the transversal direction (rad/s)
ω_{ny}	angular frequency of the system in the longitudinal direction (rad/s)

present a new design of a hyperstatic net-beam structure and an optimal dynamic analysis of the vibrating screen. Finite element models of the screen were developed and the new screen proves to have much higher structural strength with an enhanced dynamic behavior. More recently the author of this paper proposed a general theoretical model to study the dynamic behavior of high loaded vibrating screens (Baragetti and Villa, 2014). A general dynamic theoretical model is proposed and a procedure for dynamic optimization of the main parameters of a screen is described. Dynamic and static finite element models of a high loaded screen were developed and the theoretical procedure was implemented in Matlab®. Tests were carried out on a full scale screen in order to confirm the theoretical and numerical models. A complete experimental strain gages campaign was prepared and several dynamic tests were carried out confirming the values of the dynamic stresses calculated through the FEM models. The model presented in Baragetti and Villa (2014) is the most complete and recent one. For this reason it is used in this paper to quantify the dynamic behavior of the original and of the new modified screen. The particle flow might have influence on the dynamic behavior and resistance of the screen too. DEM (Discrete Element Method) was used to simulate the particle flow in vibrating screens in Dong et al. (2009), Cleary et al. (2009a,b), Zhao et al. (2011), Wang and Tong (2011), Li et al. (2003). In Dong et al., 2009 the authors consider a banana screens of large dimensions (three decks or five decks). Numerical experiments (3D DEM models) were used to set and control the performances of the screens, useful to optimize and control the screening process. Screens performances were improved by reducing the operating amplitude and frequency of vibrations. In (Cleary et al., 2009a,b) a large double deck banana screen for high accelerations was studied and the DEM method was implemented to study and improve the performances. Different peak accelerations were simulated. In (Zhao et al., 2011) and (Wang and Tong, 2011) the Authors simulate the screening process on a circularly vibrating screen using 3D-DEM and evaluated the screening efficiency and screen length of a linear vibrating screen. In (Li et al., 2003) the DEM numerical method was used to simulate particle motion. Particle kinetics and motion were treated in other references (Liu, 1999; Beunder and Rem, 1999; Soldinger, 1999; Soldinger, 2002; Soldinger, 2000). In (Liu, 1999) the author gave guidelines to check the screening performance and efficiency and checked the effects of many process parameters. In (Beunder and Rem, 1999) the authors report an accurate study of the screening dynamic motion of cylindrical particles. Full scale tests were conducted by using a CCD-camera and an image analyzing software. The measurements give a good prediction of the grade of separation and the particle distribution is like the one of a closed surface. In (Soldinger, 1999; Soldinger, 2002; Soldinger, 2000) the author reports studies on the transport velocity of the material on the screen, the analysis of the mechanisms of stratification and passage of the material through the screen and the study of the effect of particle size on the screening performance. After the accurate analysis of the literature papers dealing with the study of the particle flow in the screen, it was decided not to consider the effects of the particle flow in the design of the new modified screen. Particle flow depends of the screen process acceleration and amplitude of vibration and does not have any effect of the dynamic behavior of the machine or its structural resistance. Therefore it was decided not to consider this

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