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OPTIMIZATION OF THE HOISTING SYSTEM OF VEHICLE

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ABSTRACT
This paper forms an integrated approach of optimization model for vehicle and model of minimization of referred mass of rotational elements. Optimization model with the criterion of minimal consumption vehicle include kinematics and dynamics parameters, technical regulations set before hoisting system and recommendations for the performing of some partial calculations. Minimization model of referred mass of rotational elements take into account referred mass of motor rotor, sheaves, drums, and gear transmission. Restriction of rotation elements minimization model are based on prescribed rope angling and disposition of excavation with rotor on ground four levels. Flywheel moments for motor rotor and referred mass of elements are listed in the relevant data sheets or catalogues. We can use the approximate empirical formulas given in specialized bibliography to obtain the values of referred mass for hoisting elements.
Key words: vehicle, rotational elements, referred mass, variation calculus, optimization model.

1. INTRODUCTION
Optimization of the hoisting system should cover the following, kinematics and dynamics of the hoisting system, technical regulations for the hoisting system and recommendations for the performing of some partial calculations. Top performance of hoisting system can be obtained only if both the hoisting cycle and all the components parts of hoisting system are combined: effectively to contribute to the final result. This paper will consider the hoisting systems for vertical mining shaft with constant radius of rope winding and a three-period hoisting cycle. The load hoisting, the fundamental motion of mobile crane, is investigated and reported in recent literatures. The crane dynamic behavior during hoisting motion that is driven by a hydraulic secondary control system is simulated by [4] using a nonlinear finite element model for the hoisting system. Kaczmarczyka and Ostachowicz [1] employed the classical moving co-ordinate frame approach, Hamilton’s principle, and later the Raleigh–Ritz procedure to derive a non linear distributed-parameter for mathematical model for deep mine hoisting cables, proposed a new method based on principal component analysis (PCA) and support vector machines (SVM) for fault diagnosis of mine hoists, which includes faults associated with the gearbox, the hydraulic system and the wire rope. The research results demonstrated that the fretting wear depth of the steel wires increased with the increasing fretting cycles and contact loads. In our earlier paper [2], we made a bond graph model (linear) of a hoisting system and studied (through simulation) the dynamic response and residual behavior for fault detection and isolation. There, we considered bilateral constant threshold, which may not decouple the fault with model uncertainties and process or measurement noise [3]. Secondly, issues like isolation of structurally no isolable faults, root because analysis and estimation of remaining useful life (RUL) were not addressed therein. Now, in this work, we have surveyed different approaches available and applied to the same linear model for complete robust fault disambiguation and prognostics. The paper is organized as follows. First, we applied the adaptive threshold designed in [4] to achieve robustness

in fault detection. Next, multi-tier parallel simulation method, given by Fenestrate and Samantaray, is used for isolation of structurally no isolable faults. At last, the problem of prediction of useful life of system components [3] is addressed.

2. SETING OF THE MODEL OPTIMIZATION

Variation calculus as one of the powerful tools of a classical mathematical analysis is suitable for the solution of technical problems, and will here serve as a basis for. The solution of given task. One of the basic indicators of the operation of the hoisting system is the costs of electrical energy used for the hoisting of excavated material during the hoisting cycle. In case of hoisting systems with constant radius of winding up of the hoisting rope, the quantity of separated heat q_t, at the periphery of the drum or keeper wheel, within one cycle [5], is represented by the following equation:

$$q_t = c\int_0^T F^2 dt \tag{1}$$

Where: *c*- is coefficient; *T*- is trip time; *F*- is force at the periphery of the drum or Keeper wheel is:

$$F = g[kQ_t - (q-p)(H-2X)] + M\ddot{X} \tag{2}$$

Where: *k*- coefficient that takes resistance to movement into account; Q_t- mass of the useful load, [kg]; p- linear mass of a hoisting rope, [kg/m]; q- linear mass of balance rope, [kg/m]; M- referred mass of the system, [kg].
As a functional on the basis of whom a consumed electric power of the process under investigation can be minimized, the following functional can be written:

$$J = \int_0^T \Phi(X, \ddot{X}) dt \tag{3}$$

In the implementation on the hoisting system it is necessary to observe the restriction given by the technical regulations which provide the long term, safe and reliable operation of the hoisting system. In the expression (3) for the mass of translational elements, since they perform a straight line movement, they enter into the referred mass of the system with actual mass. Minimization of the translational mass of the hoisting system is carried out on the basis of the selection of the minimal mass of individual elements. Flywheel moments for motor rotor and referred mass of elements are listed in the relevant data sheets or catalogues. We can use the approximate empirical formulas given in specialized bibliography to obtain the values of referred mass for hoisting elements.

3. SYSTEM MODELING HOISTING MECHANISM

Represent the pitch and bounce velocity, to which are attached the inertia terms, J and M, respectively. The current-torque relation for the DC motor is idealized.

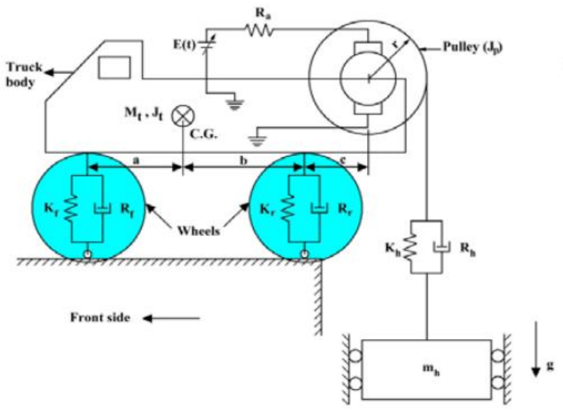

Figure 1. *Vehicle mounted hoisting system*

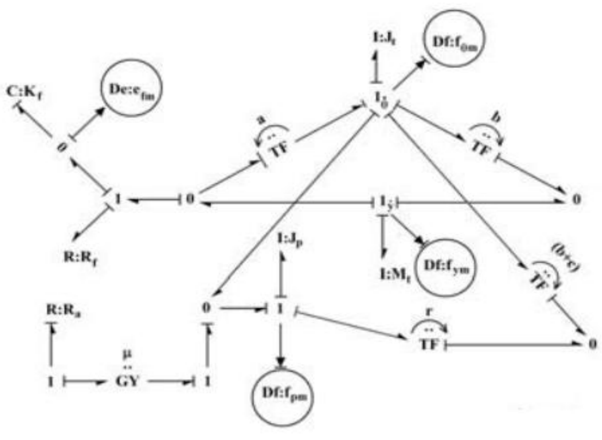

Figure 2. Bond graph model in integral causality

To isolate the faulty component FDI analysis was done there by using the algorithm given by Karnopp, Margolis, and Rosenberg [4].

Table 1. Nominal values of model parameters of hoisting mechanism

Symbol	Value	Symbol	Value
M_t	10 000 kg	R_e	1 Ω
J_t	500kg m^2	μ	1 NmA
J_p	1 kg m^2	ω	10 rad/s
m_h	100 kg	A	1 V
K_f	1x10^5 N/m	a	1 m
R_f	0.3 N s/m	b	1.7 m
K_h	1x10^3 N/m	c	0.3 m
R_h	0.1 N s/m	r	0.2m

In that algorithm, to derive the ARR all the storage elements are to be brought under preferred differential causality and negative of measured quantities from detectors are imposed on the system [3] as pseudo source and reactive factor in the bond corresponding to the pseudo source is ARR when expressed in symbolic form. The number of ARR thus derived is equal to the number of sensors installed in the plant. Seven numbers of ARR, given in the expression (3), are obtained as the same numbers of sensors are installed in the system. Two conditions for structural observables, e.g. attainability condition and sufficient condition, need to be satisfied in the first step [2]. Attainability condition states that, in integrally causally model, each storage element has a causal link to each observer (sensor). Sufficient condition will be satisfied when all the storage elements can be assigned derivative causality without violating the junction causality norm, with dualisation of sensor causality permitted. It is observed from (Figure 2) that both the conditions are satisfied, and hence the system is structurally observable.

$$ARR_1 : -m_h \cdot g - m_h \cdot \frac{d}{dt}(f_{hm}) + (e_{hm} + R_h(r \cdot f_{pm} + f_{ym} + (b+c) \cdot f_{\theta m} - f_{hm})) = 0 \tag{4}$$

The ARR_1 in the expression (4) can also be obtained from the diagnostic bond graph (DBG) shown in (Figure 2) and the FSM can be obtained directly from the causal analysis on DBG [1]. This was based on the use of a set of substitutions, which lead to a graph structure, called a DBG model, where sensor data from the system become inputs and residuals become outputs. Analysis of the causal paths to each residual is used to generate fault signatures. The flow in the bond connected to this sensor is the reactive factor of power, which is nothing but a residual. This element can then be represented as an effort source (measurements from real process), and a virtual flow sensor (DF*) is attached to measure the flow or residual (Figure 2). Such virtual sensors have computational existence, only. The DBG for the system considered is shown in (Figure 2), and the ARR given in the expression (4) can be derived by writing the expressions of the corresponding virtual sensors. Also, the residuals can be obtained numerically from DBG, if the symbolic form is not available due to existence of implicit causal loop. The FSM can then be obtained by direct exploitation of causal paths. The fault signature obtained from ARR_1 of the expression (4) is identical to the one obtained through the analysis of the causal paths. As an example, consider the virtual sensor for residual is represented in (Figure 2). The following are the causal paths to that residual. From these causal paths, the components involved in the residual are obtained as:

$$\begin{aligned}
&ARR_2 : (b+c) \cdot f_{\theta m} + f_{ym} + r \cdot f_{pm} - f_{hm} - \frac{1}{K_h} \cdot \frac{d}{dt}(e_{hm}) = 0 \\
&ARR_3 : f_{ym} + b \cdot f_{\theta m} - \frac{1}{K_r} \cdot \frac{d}{dt}(e_{rm}) = 0 \\
&ARR_4 : f_{ym} - a \cdot f_{\theta m} - \frac{1}{K_f} \cdot \frac{d}{dt}(e_{fm}) = 0
\end{aligned} \tag{5}$$

This is a more accurate drawing of the hoisting system. The drum is located inside the draw works, and is the spool that the drill line is wound up on when raising the traveling block. The crown block is located at the top of the derrick (the crown) and the drill line is strung between the crown block and the traveling block. On the bottom of the traveling block is the hook, where the drill string, casing, etc. is suspended. The end of the drill line that is wound up on the draw works is called the fast line; the other end is attached to the deadline anchor on one of the derrick legs, and is called the dead line. Extra drill line is stored on a storage reel. Since this will be the heaviest casing string run, the maximum mast load must be calculated. Assuming that 10 lines run between the crown and the traveling blocks and neglecting buoyancy effects, calculate the maximum load. A rotary rig hoisting system is given in (Figure 3).

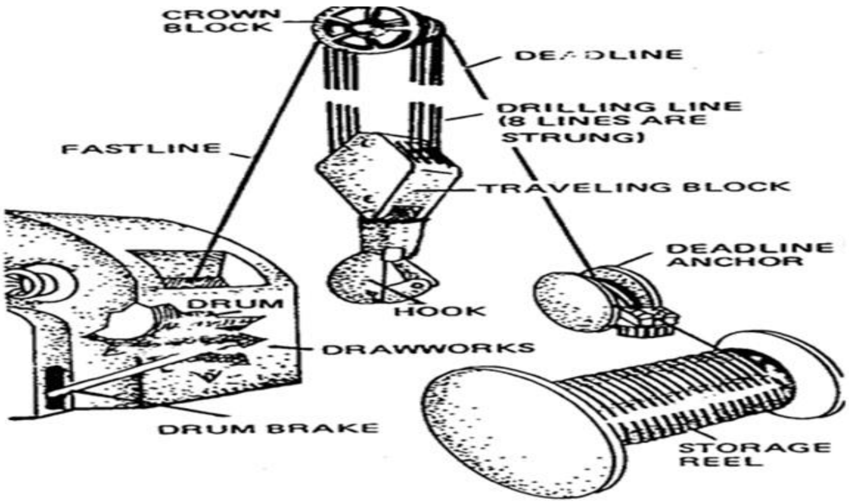

Figure 3. A rotary rig hoisting system

4. CONCLUSION

This paper forms an integrated approach of optimization model for a mine hoisting system cycle and mathematical model of minimization of referred mass of rotational elements. The proposed model of optimization includes kinematics and dynamics of the hoisting system, technical regulations set before the hoisting system, partial recommendations for the performing of the calculation within the system and minimization of the referred mass of hoisting system. The proposed models can simultaneously include the problem of optimal selection of elements of the hoisting system and optimal hoisting cycle with criterion of minimal consumption of electrical energy during the hoisting cycle. The scheme of achieving robust diagnosis is applied to ensure no misdetection and false alarm in fault detection. We have designed an adaptive threshold which can decouple the effect of parameter uncertainty and thus enhancing robustness of FDI. It is shown that the structurally no isolable faulty components can be isolated through parallel multi-tier simulation scheme. The online estimation of parameters has been used for prognostic analysis also.

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