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SYSTEM OF COMPUTER MODELLING OF SKIP DYNAMICS IN SHAFT

Summary. Mathematical simulation models are finding at present
a wider application in the spheres where another mode of inve-sti-
gation is not possible or it's too difficult. That is also the
case in processes of vertical hoisting through a shaft where a com-
puter is becoming the only easily available means for analysis and
prediction of the actions occuring in the systems.
        This paper decribes not only subsystem conveyance – shaft equip-
ment based on the system of nonlinear differential equations that
express the dynamic behaviour of the skip in three dimensional
space but also whole computer application system of analysis.

1. INTRODUCTION

Hoisting equipment represents one of the most sensitive component of
a minesystem with regard to its function of interconnection of under-
ground subsystems. The result is that the reliability of operation of
hoisting equipment has a significant influence upon the overall reliabi-
lity of the operation of a mine. The necessity of planning in mines with
great depth of coal mining requires the knowledge of the dynamic phenomena
occuring during hoisting in winding systems.

Hoisting equipment represents a sphere where mathematical models may,
above all, prove their effectiveness with regard to the complications
resulting from experimental approach. It's mainly the problem of high
costs and the necessity of ensuring the safety of measurement in the
shaft.

2. MATHEMATICAL MODEL OF TRAVEL OF SKIP THROUGH SHAFT

The simulation mathematical model of the subsystem skip – shaft equip-
ment simulates the dynamic phenomena in the horizontal plane of the skip
where the source of oscillating movement is formed mainly by random de-
viations of the tracks guiding the skip in the shaft from an ideal verti-
cal. From the point of view of completeness of the evalution of the hori-
zontal dynamics of the skip it is necessary to consider not only the phe-
nomena occuring in the face plane – the plane connecting the axes of

opposite tracks, but also the phenomena occuring in the lateral plane
which is perpendicular to the face plane. Only a thus conceived model
can be used for various numerical experiments, analyzing in general the
dynamic behaviour of the skip in horizontal direction. The diagram of
such model is shown in fig. 1, where the springs indicate the wheel guides
of the skip. The sources of the random horizontal movement are the
unevenesses of the skip tracks described by the functions $u_1(t)$ and
$u_2(t)$ indicating deviation of tracks in the face plane and by functions
$q_1(t)$ and $q_2(t)$ indicating deviation of tracks in lateral planes. Skip
so released has five degrees of freedom and its movement is described by
five second – order differential equations in the following form:

$$m.\ddot{x} + \sum_{i,j=1}^{2} (-1)^j . (k_{ij} . x_{ij} + b_{ij} . \dot{x}_{ij} + F_{prij}) = 0$$

$$m.\ddot{y} + \sum_{i,j=1}^{2} (k_{bij} . y_{ij} + b_{bij} . \dot{y}_{ij} + F_{prbij}) - $$

$$- \sum_{i,j=1}^{2} (k_{fij} . y_{ij} + b_{fij} . \dot{y}_{ij} + F_{prfij}) = 0$$

$$I_x.\ddot{\alpha} + \sum_{i,j=1}^{2} (-1)^i . h_i . (k_{fij}.y_{ij} + b_{fij}.\dot{y}_{ij} + F_{prfij}) + $$

$$+ \sum_{i,j=1}^{2} (-1)^{i+1} . h_i . (k_{bij}.y_{ij} + b_{bij}.\dot{y}_{ij} + F_{prbij}) = 0$$

$$I_y.\ddot{\Psi} + \sum_{i,j=1}^{2} (-1)^{i+j} . h_i . (k_{ij}.x_{ij} + b_{ij}.\dot{x}_{ij} + F_{prij}) = 0$$

$$I_z.\ddot{\tau} + \sum_{i,j=1}^{2} (-1)^j . r . (k_{fij}.y_{ij} + b_{fij}.\dot{y}_{ij} + F_{prfij}) + $$

$$+ \sum_{i,j=1}^{2} (-1)^{j+1} . r . (k_{bij}.y_{ij} + b_{bij}.\dot{y}_{ij} + F_{prbij}) = 0$$

where

$i = 1$ - head of skip $j = 1$ - left side of skip

$i = 2$ - bottom of skip $j = 2$ - right side of skip

m - mass

I_x, I_y, I_z - moments of inertia

k_{ij}, k_{fij}, k_{bij} - equivalent elastic coefficient for wheel ij and
                            shafttrack in face and lateral planes (f - front
                            wheel, b - back wheel)

b_{ij}, b_{fij}, b_{bij} - damping

$F_{pr(f,b)ij}$ - preload on wheel ij

x_{ij}, y_{ij} - deformation of the wheel in point ij

$$x_{ij} = x_{ij} \left[x, \psi, u_j(t) \right]$$

$$y_{ij} = y_{ij} \left[y, \alpha, \tau, q_j(t) \right]$$

Apart from the influence of the unevenesses of the tracks it's also
necessary to respect the variable rigidity of the tracks, the possibility
of loss of the wheel quide with the track or possibility of hard contact
of the skip with the track and also the important influence of eccentri-
cities of individual wheel guide.

The system of equations describing the movement of the skip in shaft
can solved (owing to the random character of kinematic disturbance by
unevenesses of tracks) practically only by means of approximate and nume-
rical methods. In this case the Runge-Kutt four-step method was applied,
which is fully satisfactory for given type of tasks.

3. COMPUTER APPLICATION SYSTEM DYCON

Computer application system DYCON (DYnamics of CONveyance) is the sys-
tem of program moduls that represents effective tool for analysis of com-
pleteness dynamic behaviour of subsystem. The system enviroment includes
base modul for numerical integration of differential equations, moduls
for preparing of input data, modul using computer graphics and important
moduls for applying classic and dynamic statistics.

Input data are created in the form of two files. The first - file of
unevenesses - can be generated by random generator or by values measured
in the real conditions of shaft, the second - file of parameters - inclu-
des parameters of winding as speed, mass, moments of inertia etc.

Statistic moduls are able to analyze individual processes or relations
between them by using theory of random processes. It's possible for indi-
vidual processes to devide it into levels, compute and draw their histo-
gram or it's possible to find auto-correlation function by the formula:

$$Kxx(\tau) = \frac{1}{T-\tau} \int_0^{T-\tau} x(t) \cdot x(t+\tau) \, dt$$

where:

T   - length of process,

τ - delay,

x(t)   - random process (input kinamatic disturbance, accelerations of skip etc.)

a compute and draw frequency spectrum by the formula:

$$Sxx(f) = 4 \int_0^\infty Kxx(\tau) \cdot \cos(2\pi f \tau) \, d\tau$$

where:

f - frequency.

By means of this method main frequencies can be found. Relations between processes, espetially between random input kinematic disturbance and output model quantities, are analyzed by formulas:

$$\gamma^2 = \frac{|Sxy|}{Sxx \cdot Syy}$$

$$|H(if)| \quad \frac{\sqrt{Syy}}{\sqrt{Sxx}}$$

and

$$\Theta xy(f) = \arctan \frac{Im(Sxy)}{Re(Sxy)}$$

where:

γ^2 - coherent function,

Sxy   - cross - spectrum,

$|H(if)|$ - modulus of transfer charakteristics,

$\Theta_{ixy}(f)$ - phase shift function.

The first - coherent function - enables to test linearity of subsystem skip - shaft equipment that is nonlinear in general, but in a case of value of coherent function going up to one it is possible to consider this subsystem as a linear and input kinematic disturb process multiply by balues of amplitude charakteristics $|H(if)|$ to get output processes with phase shift $\Theta xy(f)$. This property is very useful for measuring in actual shaft where it is necessary to measure only the input process and the output process can be determined by computed the functions.
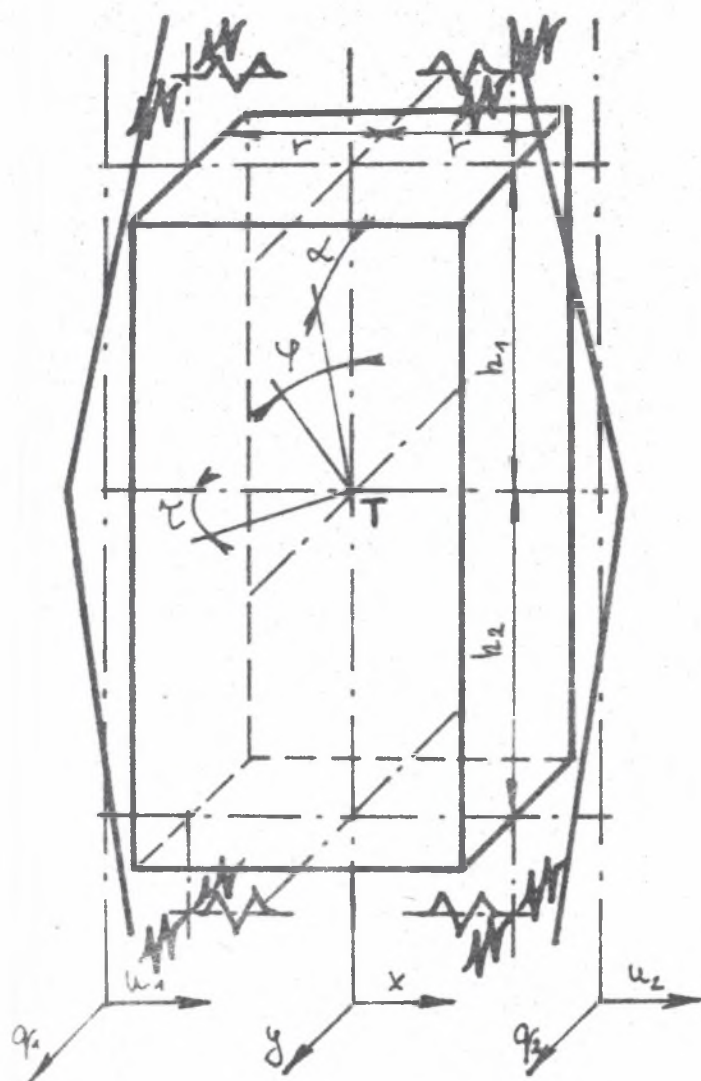
Fig. 1.

Fig. 2.

The results of the numerical integration are expressed by means of computer graphics for the clear survey of all kinematic and dynamic values (fig. 2). The picture is devided into three basic parts - front, plan and side view where the skip movement and the track unevenesses as well as the acceleration and force variables are shown.

The whole system DYCON is written in Turbo-Pascal on computer PC AT. and operates as windows interactive "user friendly" system.

4. CONCLUSION

Already during its short existence the system DYCON unveiled some phenomena whose causes had remained concealed so far as for instance influence of speed on dynamic forces. The mathematical model was aldo compared with experimental data, and the difference between the theoretical and measured values was 10%. To be entirely employed in planning and design practice, it requires further comparisons to determine its validity.

5. LITERATUR

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Recenzent: Prof. zw. dr hab. inż. Jerzy Antoniak

SYSTEM KOMPUTEROWEGO MODELOWANIA
DYNAMIKI KUBŁA SKIPOWEGO W SZYBIE

S t r e s z c z e n i e

   Modele matematycznej symulacji znajdują obecnie szersze zastosowanie
w obszarach, gdzie inne techniki badań są niemożliwe lub zbyt trudne do
wykorzystania. Tak jest również w przypadku pionowego wyciągu przez szyb.
Komputer staje się jedynym łatwo dostępnym środkiem dla analizy i przewi-
dywania działań występujących w układzie.

   Niniejszy artykuł opisuje nie tylko podsystem wózek-wyposażenie szybu
w oparciu o nieliniowe równania opisujące dynamiczne zachowanie skipu
w trójwymiarowej przestrzeni, ale także, pełny komputerowy system aplika-
cyjny analizy.

СИСТЕМА КОМПЬЮТОРНОГО МОДЕЛИРОВАНИЯ
ДИНАМИКИ СКИПОВОЙ БАДЬИ В СТВОЛЕ

Р е з ю м е

   Математические модели симуляции в настоящее время находят широкое приме-
нение в областях, где другие испытательные техники немогут быть применены
или через чур трудны для использования. Так также есть в случае вертикально-
го польема (вытяжки) через ствол, где компьютор - это единственное легко
доступное средство для анализа и прогнизирования действий действующих
в системе.

   Настоящая статья описывает не только подсистему тележка-оснащение ство-
лана основании неинейных дифферинциальных уравнений, описывающих динами-
ческое поведение скипа в тройразмерном пространстве, но и также полную
компьюторную апликационную систему анализа.