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DETERMINATION OF REACTIONS AFFECTING THE MICROTUNNELLING EXCAVATOR

ŘEŠENÍ REAKCÍ V BAGRU MIKROTUNELOVACÍHO ZAŘÍZENÍ

Abstrakt

VŠB-TU Ostrava spolupracuje s firmou MT Prostějov při konstrukci a vývoji mikro-tunelovacích zařízení. Jedním z požadavků této firmy byl vývoj a konstrukční řešení mikro-tunelovacího zařízení DN 1200 s razícím štítem a bagrem. Toto zařízení je velmi vhodné do městských aglomerací, protože je schopné zaregistrovat překážky (energovody, kanalizace, kabelové vedení atd.) a následně je nepoškodit. Princip práce tohoto zařízení je popsán ve firemní literatuře a prospektech např. firem HERRENKNECHT nebo TAUBER.

Annotation

Company MT Prostějov cooperates with VŠB-TU Ostrava on a design and a development of microtunnelling machines. The company applied for a development and design of a microtunnelling machine DN 1200 with a tunnel shield and an excavator. This system is appropriate for an application in a congested city agglomeration because it is able to detect an unexpected obstacles (sewers, underground lines, power-transmission lines etc.) and doesn't damage them. The principle of a work of this system is described for example in HERRENKNECHT or TAUBER materials.

Designed machine

The focus of solution was to design a mechanism of a microtunnelling system excavator. The excavator (Fig. 1) was designed in accordance with given requirements. It works in three main modes:

- ❑ Disintegration of soil
- ❑ Scraping off soil
- ❑ Carrying the soil to a conveyor belt

The new designed digger improves the excavator capabilities particularly in mode of carrying the soil to a conveyor belt. Its capabilities in other functional modes were retained.

Design of the excavator has been made in Pro/ENGINEER CAD system and the created model was analysed in Pro/MECHANICA – MOTION and STRUCTURE. Determination of reactions affecting the excavator mechanism is very important for a design (proper shape and suitable material) of mechanism parts.

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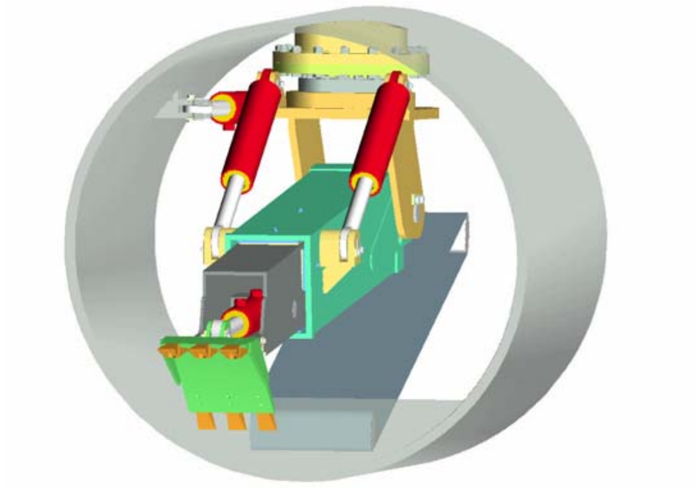

Fig. 1- 3D model of the designed excavator with simplified tunnel shield and belt conveyer

Model for evaluation of reactions

The model of excavator mechanism for evaluation of reactions is quite complicated. The model was created in Pro/MECHANICA – MOTION, which is an extended tool of CAD system Pro/ENGINEER. A new approach to the simulation of hydraulic cylinders was used. A force and a damper instead of a driver were applied on a translational axis of SLIDER joint of the hydraulic cylinder model. The force (Joint axis load) of the maximal value the hydraulic cylinder can generate is defined on the SLIDER joint axis. Then a damping (Joint axis load – Damper) is defined on the same axis as the force. It is defined as a product of the set damping coefficient and the speed in the direction of the damping axis. If the damping coefficient is sufficient, the mechanism stays in the initial position during the MOTION analysis. This method of hydraulic cylinder simulation allows only static analysis of the mechanism in a specific position. The advantage of this method is that it can be used in a model of mechanism with redundant kinematic structure (two cylinders for one motion). Sliding bushings which allow tipping of extensible jib were simulated as bearings (BEARING joint). The redundancy causes that the correct reactions affecting the bushings are not evaluated unless the new method of hydraulic cylinder simulation is used. The simulative model of mechanism was optimised but the effort to eliminate the redundancy failed.

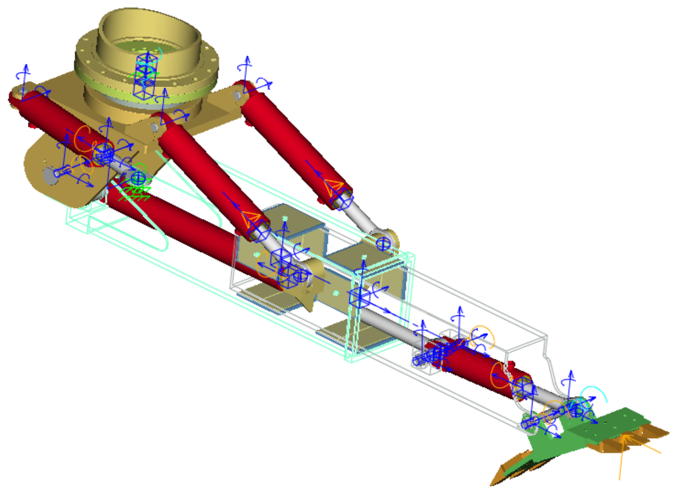

Fig. 2 – The simulative model of the excavator mechanism

Reactions evaluated by analysing the model can be used in STRUCTURE module during stress analyses of single parts of mechanism. The disadvantage of the model with cylinders simulated as force and damping is that it can be used only in static analysis. That's why the model served for verification of results obtained by kinematic analyses and for evaluation of reactions during static analyses in significant positions.

The analyses of the model with cylinders simulated as force and damping proved that the reactions affecting the cylinders and the bushings aren't evaluated correctly. This causes the redundancy of the model of the kinematic structure. The reactions which should be divided between two cylinders and bushings affect only one cylinder and one bushing. The model for evaluation of reactions is shown on Figure 2.

Results of analyses

Kinematic analyses proved that the excavator mechanism is able to reach every point of the required working space. The reactions affecting the parts of mechanism were evaluated during dynamic analyses for all working modes. In this contribution results of analyses for soil scrape off working mode are presented. Simulation conditions are shown on Figure 3, maximal extension of the jib and movement of the digger downwards in vertical plane which goes thru the longitudinal axis of the tunnel shield. Resistance force (F_O) affecting the digger was assessed on 5000 N.

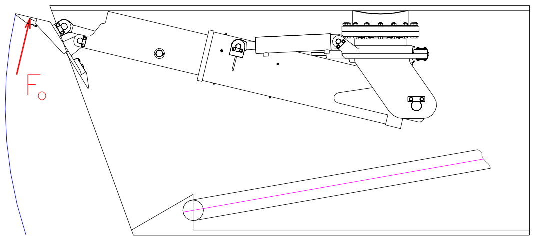

Fig. 3 – scheme of scrape off soil working mode

One of the most important parts of the excavator is the slewing ring. Values of overturning moment, axial and radial force affecting the slewing ring during the simulation are shown on Figure 4 and Figure 5.

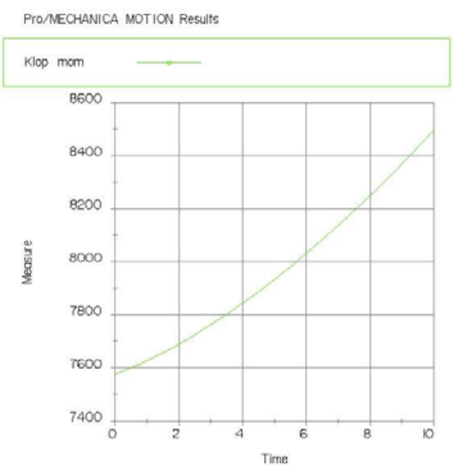

Fig. 4 – Overturning moment

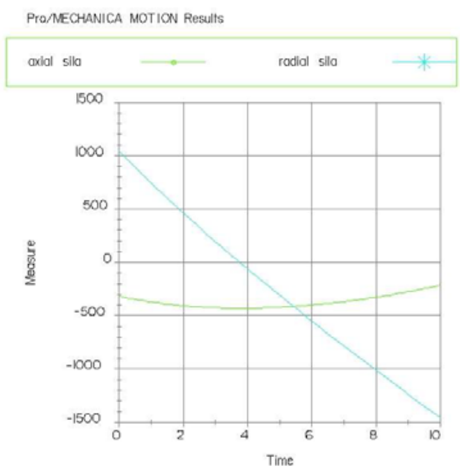

Fig. 5 – Axial and radial force

$M_{OK}(0)$ = 7577 Nm
$M_{OK}(10)$ = 8496 Nm

$F_{OA}(0)$ = -316 N
$F_{OA}(10)$ = -211 N

$F_{OR}(0)$ = 1045 N
$F_{OR}(10)$ = -1459 N

Other important parts are sliding plates of the extensible jib. Reactions affecting the front and rear sliding plates are shown on Figure 6 and Figure 7 respectively. Negative values of reactions signify that the upper plates are stressed, while positive values signify stress of bottom plates. Reactions affecting the sliding plates were checked by manual calculation in simulation time 5 s. Differences were ± 50 N.

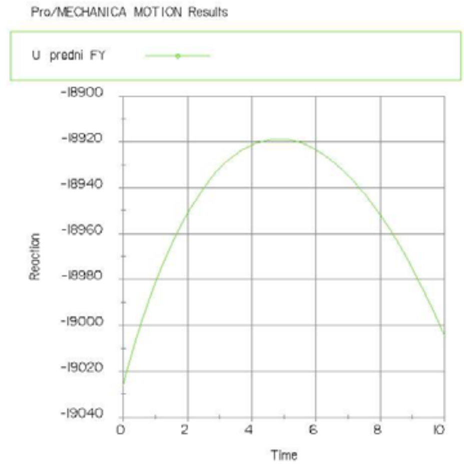

Fig. 6 – Reactions affecting front sliding plates

A_{ymax} = -19026 N

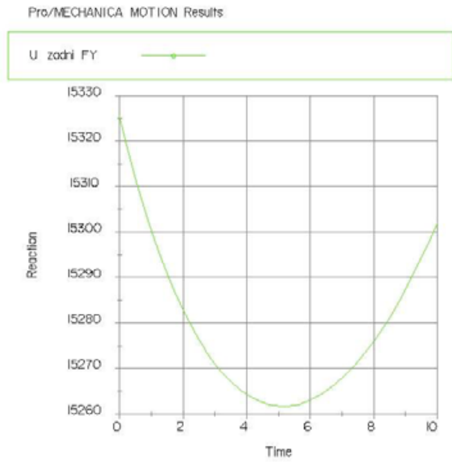

Fig. 7 – Reactions affecting rear sliding plates

B_{ymax} = 15326 N

Reactions affecting other parts of an excavator mechanism were evaluated in the same way. Then they were used in stress analyses of excavator mechanism parts in STRUCTURE module.

Conclusion

The design of microtunnelling machine shield excavator mechanism was aided by CAD system Pro/ENGINEER. Model which allows the evaluation of reactions affecting the excavator mechanism was successfully created in MOTION module. Reactions were consecutively used in STRUCTURE module in stress analyses of the designed mechanism parts.

References

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