46th International Scientific Conference EXPERIMENTAL STRESS ANALYSIS 2008
Department of Mechanics of Materials, VŠB - Technical University of Ostrava
June 2 - 5 2008, Horní Bečva, Czech Republic

Karel FRYDRÝŠEK*, Horst GONDEK**

SOLUTION OF HARD ROCK DISINTEGRATION PROCESS

ŘEŠENÍ PROCESU ROZPOJOVÁNÍ TVRDÝCH HORNIN

Abstract

This paper is focused on the numerical analysis of the hard rock (ore) disintegration process. It will discuss the possibility of using computational modelling for the mechanical contact problem between the hard rock and the cutting bit. The bit (i.e. an excavation tool with a flat frontal side and a conical edge) moves and sinks into the hard rock and subsequently disintegrates it. The whole problem of the hard rock disintegration process (i.e. stress-strain relationship, contact forces, reaction forces and fracture of the ore) is solved via Finite Element Method (MSC.MARC/MENTAT software). Some results (reaction forces in the cutting bit etc.) are also compared with experimental measurements.

Abstrakt

Tento článek je zaměřen na numerickou analýzu rozpojování tvrdých hornin (rud). Což je problém počítačového modelování problematiky mechanického kontaktu mezi tvrdou horninou a řezným nástrojem. Nůž (tj. rozpojovací nástroj s plochým čelem a kuželovým břitem) se pohybuje a vniká do tvrdé horniny a následně ji rozpojuje. Celá problematika rozpojování tvrdých hornin (tj. napěťově-deformační stav, kontaktní síly, reakční síly a lom rudy) je řešená pomocí Metody konečných prvků (MSC.MARC/MENTAT software). Některé výsledky jsou také porovnány s experimentálními měřeními.

1 FINITE ELEMENT MODEL OF THE ORE DISINTEGRATION PROCESS

Science/technical development supplies new ways for the solution of the ore disintegration process, see Fig.1. Hence, Finite Element Method (FEM, MSC.MARC/MENTAT 2005r3 software) was used in solution of the ore disintegration process. The basic boundary conditions and loads are described in Fig.2 where u and v are prescribed displacements in X-axis and Y-axis directions. The bit is moving into the ore by the prescribed time dependent function $u = f(t)$. There is also a mechanical contact with Coulomb's friction between the bit and platinum ore.

Fig. 1 Typical Example of Mechanical Interaction within the Bits and Hard Rock (i.e. Ore Disintegration Process).

* MSc., Ph.D., ING-PAED IGIP, Department of Mechanics of Materials, Faculty of Mechanical Engineering, VŠB-TU Ostrava, 17. listopadu 15, Ostrava, tel. (+420) 59 732 4552, e-mail karel.frydrysek@vsb.cz
** Prof., MSc., DrSc., Department of Production Machines and Design, Faculty of Mechanical Engineering, VŠB-TU Ostrava, 17. listopadu 15, Ostrava, tel. (+420) 59 732 1208, e-mail horst.gondek@vsb.cz

Isotropic and homogeneous material properties was applied. The bit is made of sintered carbide (sharp edge) and steel. The ore material is elasto-plastic with yield limit $R_p = 12$ MPa and fracture limit $R_m = 13.5$ MPa. When the bit is moving into the ore the equivalent von Mises stresses: σ_{HMH} in the ore increases. When the situation $\sigma_{HMH} > R_m$ occurs in some elements of the ore, then these elements break off (i.e. these elements are dead). Hence, the disintegration of a part of the ore is done.

Four parallel computers (AMD Opteron 848, 4 GB RAM) were used to solve the large computational needs of this problem.

2 RESULTS OF FEM

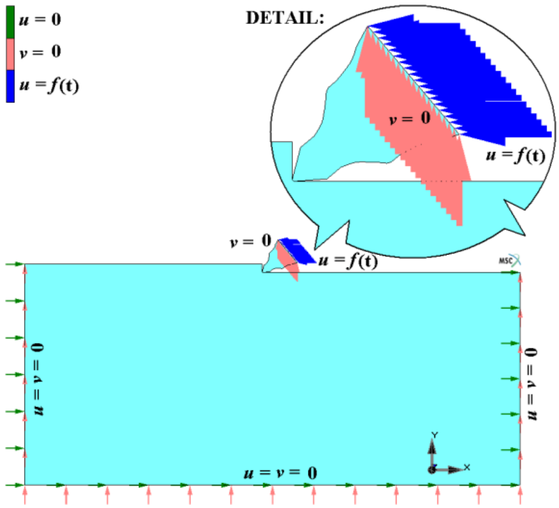

Fig. 2 Boundary Conditions Scheme of the 2D Model (Plane Strain Formulation).

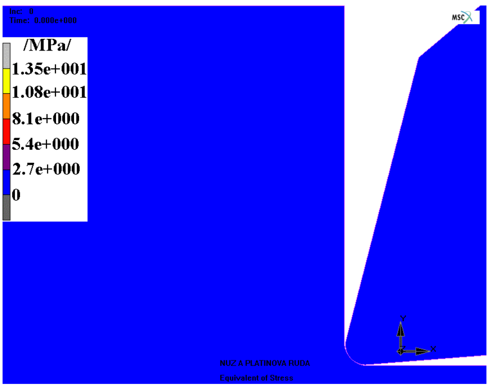

Fig.3 - t =0 s (Start of the Solution).

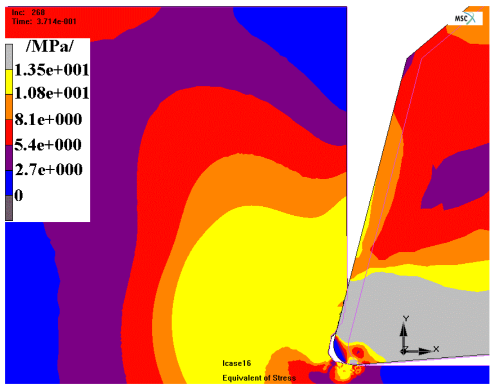

Fig. 4 - t = 3.714×10^{-1} s.

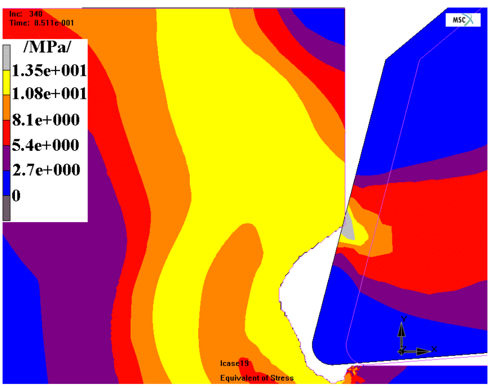

Fig. 5 - t = 8.511×10^{-1} s.

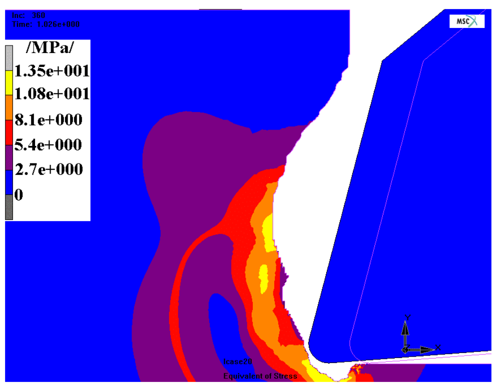

Fig. 6 - t = 1.026 s.

The figures 3 to 6 show σ_{HMH} distributions at some chosen time t. The moving of the bit is evident and also the subsequent disintegration of the ore caused by the cutting bit. From the results of FEM the reaction forces R_X, R_Y and total reaction force R which act in the bit, can be calculated, see Fig.7. The maximum reaction force (acquired by FEM) is $R_{MAX_{FEM}} = 4598\,N$.

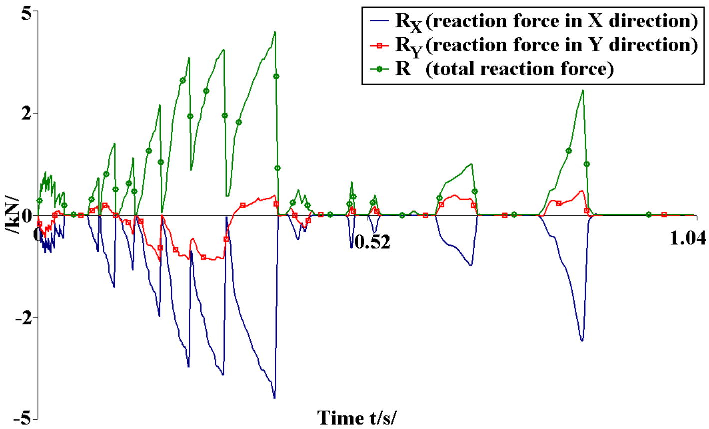

Fig. 7 Reaction Forces in the Bit.

3 COMPARSION OF FEM RESULTS WITH EXPERIMENTAL MEASUREMENTS

The calculated forces (see Fig.7) can be compared with the experimental measurements (part of Fig.8). From the evaluation of experiments, it is evident that the maximum force is $R_{MAX_{EXP}} = 5280\,N$. Hence, the relative error is:

$$\Delta_{R_{MAX}} = 100 \times \frac{R_{MAX_{EXP}} - R_{MAX_{FEM}}}{R_{MAX_{EXP}}} = 12.9\,\%.$$

However, the experiments also have a large variability of inputs caused by anisotropic and stochastic properties of the material and by the large variability of reaction forces, for example see Fig.8.

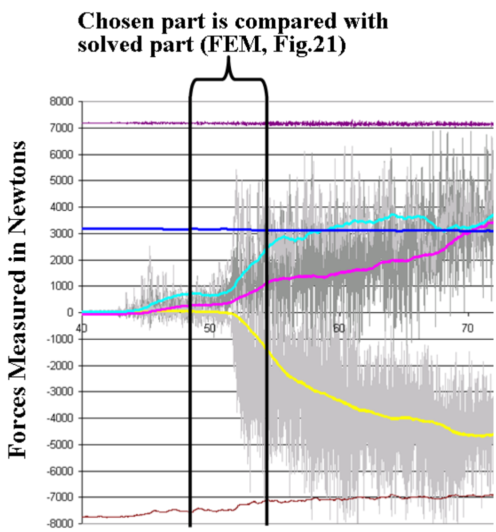

Fig. 8 Experimental Measurements and its Comparison with the FE Solution.

4 CONCLUSIONS

The error of 12.9% of the FEM result (i.e. comparing with experiments) is acceptable. Hence, FEM can be useful tool for the solution of the ore disintegration process. All results were applied for optimalisation and new design of the bit.

In the future will be applied 3D FE models (instead of 2D plane strain formulation), which can be more accurate.

Because the material of the ore (i.e. yield limit, fracture limit, Young's modulus, Poisson's ratio etc.) has large variability, the stochastic theory and theory of probability can be applied. Hence, in the future the whole presented problem can be solved via the SBRA Method (Simulation Based

Reliability Assessment Method). The SBRA Method, which is based on Monte Carlo simulations, can include all stochastic inputs and then all results are also of stochastic quantity.

For more details see full version of this contribution.

The work has been supported by the project FRVŠ 534/2008 F1b.

REFERENCES

[1] *Collection of documents of Long Airdox Company*.

[2] *Technické výsledky ověřovacího provozu DBT u fy. Angloplatinum* - DBT-project Long – Airdox Limited, hallam Fields Road, ILKESTON Derbyshire, England 2000, (Geology – Union tech. Angloplatinum, Technické informace publikování Daily Minnery + Minervy Noc Jurnal 1999, Laboratorní výsledky Angloplatinum – uniaxial komprese structual test horniny Varenský, UG – 2).

[3] *Collection of documents of Voest-Alpine*, Bergtechnik Company. (In Czech).

[4] BOROŠKA, J., GONDEK, H., ZAJAC, O.: *Hlbinné dobývacie stroje a dopravné zariadenia*, 1. vyd. Bratislava: Alfa. 1991, Kapitola 5, p. 79-86, ISBN 80-50-00713-2 (in Slovak).

[5] JONAK, J.: *Urabianie skal glowicami wielonarzedziowymi*, Slask - Wydavatelstwo Naukowe,, Katowice 2002, ISBN 83-7164-275-X. (in Polish).

[6] ZUBRZYCKI,J., JONAK,J.: *Numeryczno-eksperymentalne badania wplyvu kstaltu powierchni natarcia ostrza na obciaženie noža skrawajacego naturalny material kruchy*, Lubelskie Towarzystwo Naukowe, Lublin 2003, ISBN 83-87833-42-8 (in Polish).

[7] SIKORA,W., CHELUSZKA, P., GIZA, T., SOBOTA, P., MANN, R., OSADNIK, J.: *Okreslenie sil i energochlonnosci urabiania nożami stožkowymi*, Wydawnictwo Politechniki Slaskej, Gliwice 2000, ISBN 83-88000-58-6 (in Polish).

[8] GONDEK,H., JURMAN,J.: *Porubové kombajny a jejich konstrukce*, Skripta VŠB, Ostrava 1983, 75 pp. (in Czech).

[9] FRYDRÝŠEK, K., VÁCLAVEK, L.: *Solution of the Beams on Elastic Foundation (Deterministic and Probabilistic Approach)* In: Book of Extended Abstracts, National Conference with International Participation: "Engineering Mechanics 2006", ISBN 80-86246-27-2, Institute of Theoretical and Applied Mechanics, Academy of Sciences of the Czech Republic, Praha 2006, Czech Republic, pp. 70-71, (full version also on CD).

[10] FRYDRÝŠEK, K., VÁCLAVEK, L.: *Probabilistic Assessment of Beams on Elastic Foundation*, In: 8th International Scientific Conference "Applied Mechanics 2006", ISBN 80-7043-441-4, Department of Mechanics, Faculty of Applied Sciences, University of West Bohemia in Pilsen, Plzeň, 2006, Czech Republic, pp. 21-22, (full version also on CD).

[11] FRYDRÝŠEK, K., LENERT, J.: *Mechanics of Materials*, (compendium), HGF VŠB-TU Ostrava, ISBN 80-248-0806-4, Ostrava, 2005, Czech Republic, pp. 63.

[12] VALÍČEK, P.: *Řešení problematiky rozpojovacích orgánů pro stroje na dobývání platinové rudy*, (Ph.D. Thesis), FS VŠB-TU Ostrava, Ostrava, 2007, Czech Republic, pp. 76. (in Czech)

[13] MAREK, P., BROZZETTI, J., GUŠTAR, M., TIKALSKY P.: *Probabilistic Assessment of Structures Using Monte Carlo Simulation Background, Exercises and Software, (2nd extended edition)*, ISBN 80-86246-19-1, ITAM CAS, Prague, Czech Republic, 2003, pp.471.

Reviewer: MSc. Martin FUSEK, Ph.D., VŠB-Technical University of Ostrava, CZ