**DYNAMIC MODEL OF ROCK IMPACTS**

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**ABSTRACT**

Previous theoretical and experimental investigations [1]–[5] have tested the behaviour of high frequency vibro-impact drilling systems using a bilinear elasto-plastic model for the force-deformation characteristics of rocks (see Fig. 1a). There, the resistive force was proportional to the deformation of the rock before the yield stress was reached.



Figure 1: Schematics of the previous (a) and the new (b) vibro-impact drilling models with force-deformation diagram (c).

The dynamic model of a vibro-impact system incorporating the new model of the contact force is shown in Fig. 1b. In Figs. 1a and b, the drill-bit is modelled by a mass *M* driven by a combination of a static and a dynamic force *F* = *FS +FD* cos(Ωt). Here *FS* is the static force, *FD* is the amplitude of the dynamic force, and Ω is the angular frequency of the dynamic load component. While the drill-bit of mass *M* is not in contact, its dynamics can be described by:

 (1)

where *xM* is the displacement of the drill head, and *xT*,  *xB* or *xS*  are the displacements of the slider. As soon as the drill-bit contacts the rock, the resistive force *FR* also starts to act on the mass. In our new contact force model, as shown in Fig. 1b, during the loading stage (*M* >0) of the contact, the resistive force is proportional to the square of the displacement: *FR* = *a* (*xS* – *xS,prev* )2 , where *a*  is a material constant, and  *xS,prev* is the position of the slider reached during the previous impact. When the velocity of the progressing mass drops to zero(*M* ≤ 0 ) we assume that the elastic part of the deformation is regained, hence the resistive force is Hertzian: *FR* = *d*(*xS* – *xR* )3/2, where *xR* = *xS*,max – ( *FR,max* /*d*) is the remaining deformation after unloading, *xS*,max is the maximum displacement during progress, *FR,max* is the corresponding maximum resistive force, and *d* is a material constant. Hence the dynamics can be described by the following equations during impact:

 (2)

We identify chaotic and regular motion of the drill-bit, depending on the parameter settings. One can observe that the progression is higher when the motion is periodic.

To have an overview of when the motion of the drill-bit is chaotic and when it is periodic, the bifurcation diagram was also constructed for several parameter values. Two examples are shown in Fig. 3.

**References**

[1] M.Wiercigroch, R.D. Nielson, M.A. Player: Material removal rate prediction for ultrasonic drilling of hard materials using an impact oscillator approach. *Physics Letters A* **259** (1999) 91–96.

[2] E.E. Pavlovskaia, M. Wiercigroch, C. Grebogi: Modelling of an impact oscillator with a drift. *Physical Review E* **64** (2001) 056224.

[3] E.E. Pavlovskaia, M. Wiercigroch: Low dimensional maps for piecewise smooth oscillators. *Journal of Sound and Vibration* **305** (2007) 750–771.