A NEW MODEL FOR THE STUDY OF RAIN_WIND INDUCED VIBRATIONS .

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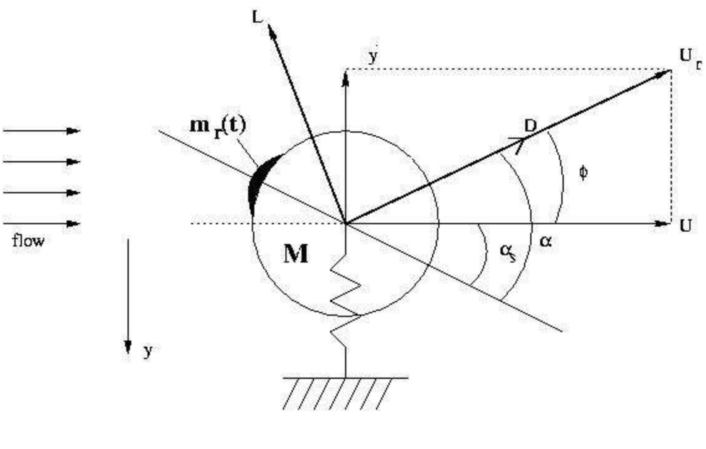
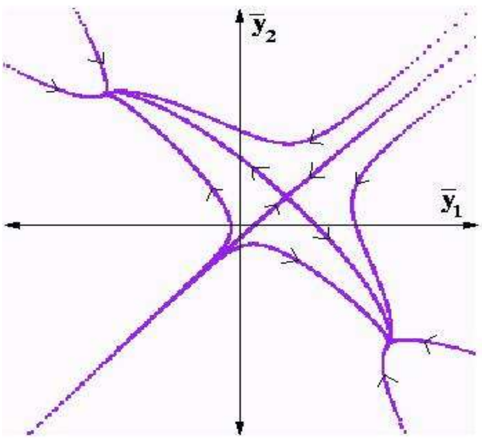
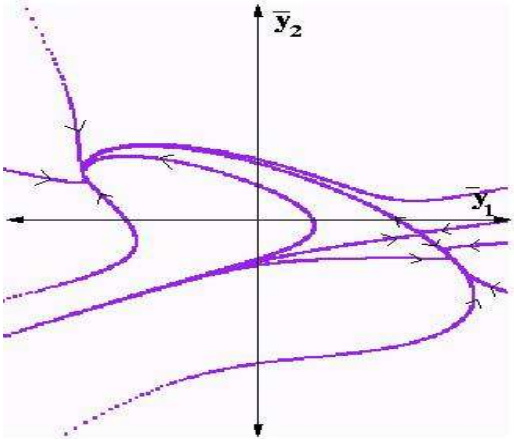
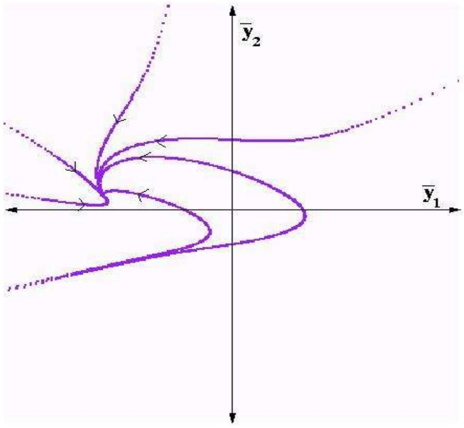
Summary In this paper model equations are presented for the study of rain-wind induced vibrations of a simple oscillator and a rod. As will be shown the presence of raindrops in the wind-field may have an essential influence on the dynamic stability of the oscillator. In this model equation the influence of the variation of the mass of the oscillator due to an incoming flow of raindrops hitting the oscillator and a mass flow which is blown and shaken off, is investigated.

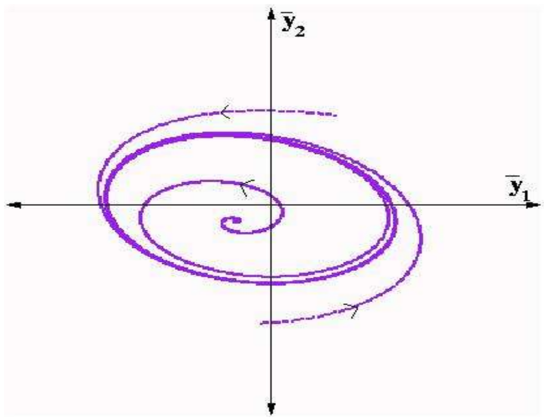
Inclined stay cables of bridges are fixed on one end to a pylon and on the other end to the bridge deck. Usually the stay cables have a polyurethane mantle and a cross section, which is nearly circular. With low structural damping of the bridge, a wind field containing raindrops may induce vibrations of the cables. The problem of rain-wind induced vibrations of stay cables has been studied experimentally in (Matsumoto a.o. (1990-1995)) and (Verwiebe and Ruscheweyh (1997)).In these papers it is remarked that regretfully calculation models are not available. A first attempt to model this problem can be found in (van der Burgh(2001)) where in particular time-varying lift and drag forces are modeled. In this paper a possible additional effect is taken into account namely the variation of the quantity of rainwater located on the cable(oscilator).Also a new model of cable as a rod interacting with a fluid has been investigated as well . In terms of modeling one can say that the vibrating mass of rainwater on the cable is time-dependent. In the first model time-dependency is modeled by a piecewise constant periodic function and a harmonic function whereas simultaneously also time-varying lift and drag force are considered. The attention for both models is focused on the interaction of the rain with the oscilator, assuming that this interaction is an instability mechanism. Raindrops hitting the oscillator may form a water ridge on the oscillator. However in a stationary situation the mass flow of incoming raindrops hitting the oscillator and the mass flow of raindrops shaken off will be equal. If these mass flows are not equal then the mass of raindrops attached to the oscillator varies with time. One may conclude that the following mechanisms may be relevant for the study of the instability of the oscillator:
1.the assumption that the mass of the ridge and hence the mass of oscillator may vary in time, seems realistic
2.drag and lift forces vary usually in the dynamic situation, however due to the fact that the position of the ridge on the oscillator is not fixed but varies with time, the aerodynamic coefficients additionally depend on time.
As the second mechanism has been studied in (van der Burgh 2001) it could be of interest to include now the additional effect of time-varying mass. It should be stressed that the dynamics of the mass of the rivulets will not be modeled by a separate equation of motion in this stage: in the modeling we assume that either the position of the rivulets is fixed or varies harmonically in time in the same way as the oscillator.From the model describing the interaction of a wind-field containing rain drops and a simple oscillator it follows that both the time-varying mass rain drops attached to the oscillator's the time-varying lift and drag force coefficients are mechanisms leading to an unstable equilibrium position. From physical point of view it can be understood that regular adding and removing of a marginal quantity of raindrops attached to a mass spring system defined as a Hamiltonian system, may lead to an unstable equilibrium.
On the other hand the time varying position of the water ridge leads to time varying lift and drag forces as an instability mechanism. When the position of the water ridge is fixed the unstable equilibrium position as evolution of three unstable critical points and two stable critical points corresponding with two periodic solution are found. In absence of variation of mass of rain water on the oscillator only one stable critical point i.e. one periodic solution is found. Apparently the first mechanism displays a certain symmetry which the second mechanism does not show.
In general the variation of position of the water ridge and the variation of mass of rain water on the oscillator give different effects to the system.Increasing the amplitude of the variation of the position of the water ridge it turns out that the system has one stable periodic solution, but when the amplitude of the variation of the mass of rain water increases the system undergoes to the situation with three periodic solutions (two stable and one unstable).When the detuning parameter varies will lead to the saddle node and Hopf bifurcation occur in the system.











For the model of a rod with the water ridge on the surface the computer simulation shows that the galloping mechanism appears near the 2^{nd} or 3^{rd} natural frequencies of the cable depending on the parameters of the cable and the inclination angle From a practical point of view one may conclude that in order to avoid instabilities one should design the oscillator in such a way that rain water accumulation and variation should not be possible.

References

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