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Dynamic Analysis of Elastic Cylinders in Rolling Contact

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1 INTRODUCTION

A common treatment in manufacturing web-like thin materials like paper or aluminum folium is to manipulate it between two cylinders under rolling contact. The rolls of such press units are typically thick-walled cylinders made of steel or cast iron. Depending on the unit process, both, only one or none of the cylinders can be covered by soft material like polymer, the purpose of which is to make the narrow contact zone larger in the direction of web propagation. The rolls are driven by two separate electrical motors, which are connected to the rolls by means of universal shafts and gears. The system lay-out is given in Fig. 1 below

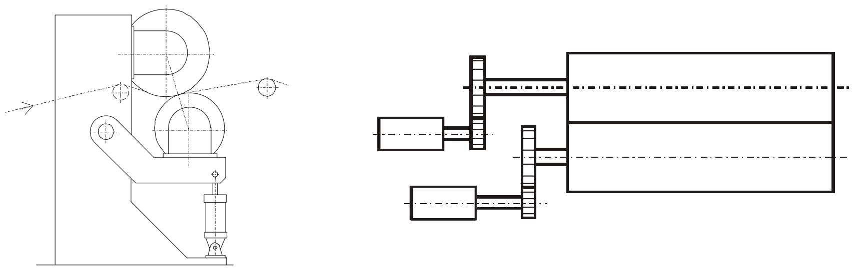

Figure 1. System lay-out of an industrial roll press for paper manipulation.

The design of a roll press requires a set of deep analyses, in which the steady-state and dynamic response behavior of the rolling process has to be investigated. A typical feature of such technical systems is that local and system level behaviors are highly connected. The local rolling contact problem in normal and tangential directions is highly nonlinear because the contact is nonconformal by nature and the response behavior of the visco-elastic cover material is a complex one. The steady-state rolling contact problem becomes then very complicated if the bending elasticity of the rolls is considered. Therefore, very often the planar problem of two layered, infinitely long cylinders is solved when the local deformations have a great importance. The bending elasticity, however, must be considered when the internal contact load distribution has to be solved for a vertical roll pair under the effect of gravitation and applied compressive loading. This leads then to an inverse problem: which profile correction, so called crowning, should the rolls have in order to produce a constant line load distribution for a given total load level. Despite of the high difficulty level the steady-state analysis of rolling contact of layered cylinders is well-understood and widely published. The dynamic response of such elements is, however, less investigated and still open for new research, because for each excitation mechanism the response behavior of the system is completely different.

2 DYNAMIC ANALYSIS

A roll press is sensitive to vibrations, which fact has been reported from many paper manufacturing companies. Press roll vibration is unwanted, because it marks the web by regular stripes. Typical vibration modes, when identified from the responses, are elastic bending and rigid body torsional vibrations of the rolls. A classification of potential excitation mechanisms has to be done in order to link certain response behavior to a corresponding excitation. The excitations can be external ones, which are transmitted by the web in terms of periodic thickness or stiffness distributions, or internal ones, which are related to the shape or elasticity distributions of the roll and layer surface (Fig. 2).

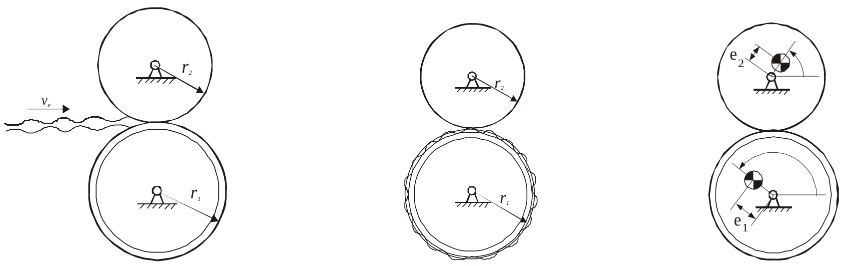

Figure 2. Internal and external excitation mechanisms of cylinders in rolling contact.

A common internal excitation source is also the distributed imbalance distribution of the rolling cylinders. The drives, especially the gears, are very often also a strong source of internal torsional excitation occurring at a fixed frequency corresponding to the gear teeth number. When such classical or parametric excitation mechanisms are working and the rolls are interacting over the contact zone, the role of the roll cover becomes very important. If the cover is viscoelastic like the polymers very often are, the delayed recovery response of the polymer during each roll revolution starts to initialize self-excited vibrations. Delay-type resonances are common at fixed running speeds after a certain threshold speed. Some fuzzy-control based speed-variation algorithms have been developed to avoid non-favorable resonance-sensitive speeds. Additional vibration damping systems based on fast piezo actuators have been introduced as well to eliminate/reduce such resonance oscillations by bringing additional damping and stiffness to the system by means of a feedback control loop.

This paper gives an overview how to approach the modeling problem of such complex rolling systems in order to predict the response behavior of a given system configuration. Such analysis can be used in conjunction with the design of a real system in order to estimate the sensitivity of the roll press subject to vibrations. One example of such analysis is the design of a pilot size roll press, in which complex system level models where used (Fig. 3). Like the similar industrial units the pilot machine exhibites also delay-type resonance behavior, the control of which by means of piezo-actuators has been the subject of the recent investigations.

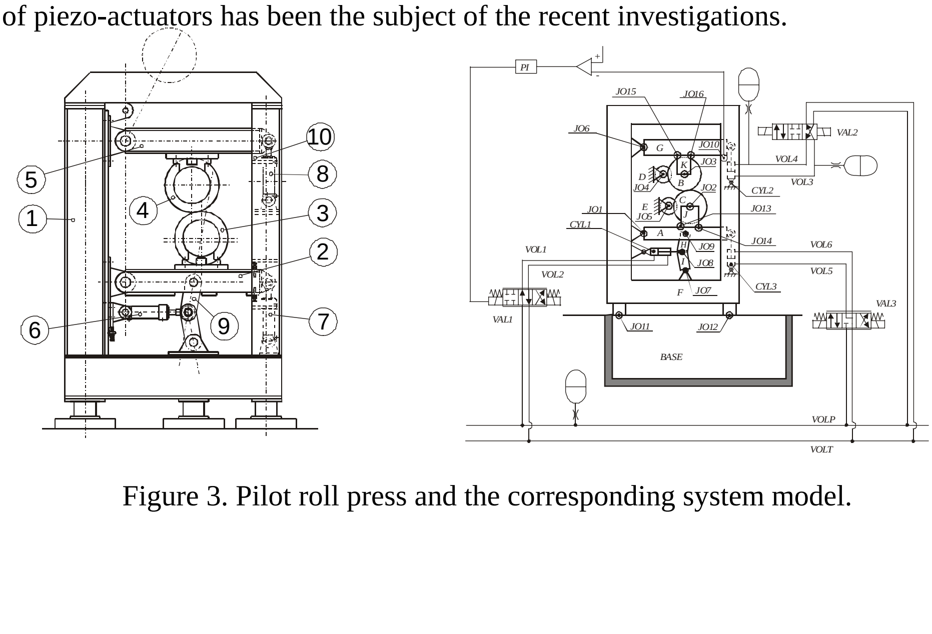

Figure 3. Pilot roll press and the corresponding system model.