DYNACON: Dynamic Control of Spring Making: Extended Abstract.

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Background

DYNACON, or DYNAmic CONtrol involves the design and implementation of an intelligent adaptive controller for the control of spring free lengths (FL) on an automatic coiling machine (the length of each spring as it comes off the coiling machine). A spring's design is specified by many parameters including its wire type, the number of coils, coil diameter and spring free-length, each of which must lie within spring tolerance. It is the FL which we wish, at this stage, to keep as near to optimum as possible. We are implementing an adaptive controller that will learn on-line both the characteristics of the coiling machine and the properties of the wire, thus increasing production rate over currently available control systems.

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The coiling process

Helical springs are manufactured on an automatic coiling machine Figure 1. Wire is fed from a coil into several drive rollers which set the wire feed rate and are spaced so as to prevent buckling or bending of the wire. The wire is then fed to a pitch tool where the wire is plastically deformed into into a helix. Usually the two end coils (lay on and lay off) are formed with a smaller pitch resulting in a varying pitch angle profile. When the spring has been formed the spring free length is measured and the spring is cut and removed from the machine. The process is then repeated. If the wire properties remain constant then the final length of the spring is determined by the coil pitch and the wire feed rate. Variations in the mechanical properties of the wire, wire friction, wire feed rate and variations in the pitch tool profile can contribute to the variability of the finished free length. By processing the measured F.L. in a computer the pitch tool can be varied about its nominal value and so control the spring F.L. Typical spring sizes are 1-50 mm in diameter with 3-20 coils/spring and typical production rates are 10000 springs/ hour or 3/sec.

Controller design

By controlling the nominal pitch tool position the free-length of a spring can be varied. Spring free-length is measured using a position sensor. It is then sampled by an AD converter and stored in the computer. The computer then processes the measurement and computes a new setting for the pitch tool. This is a regulator problem and the controller operates with a constant reference or target. If we model the process as a pure time delay and a gain then some possible adaptive control law designs which we have considered are,

- PID controller/Smith predictor.
- Minimum variance controller.
- Fuzzy logic control.
- Chaotic control

The purpose of the adaptive controller is to learn about the system and disturbance dynamics and so reduce the variance of the spring free-lengths.

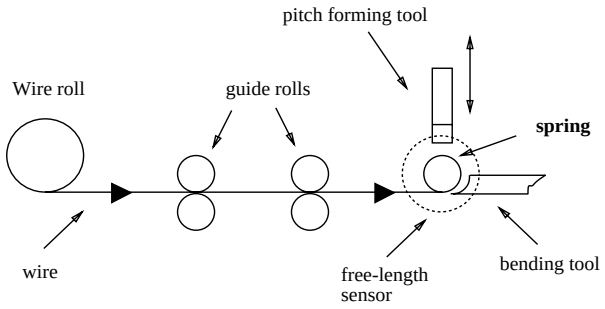

Figure 1: Automatic coiling machine

Ultimately the performance specifications translate into a reduction in the reject rate by reducing the variability of the measured free-length of the springs. One type of control law being investigated is an adaptive fuzzy logic control law. Fuzzy logic is particularly useful when the dynamics of the process are vague or poorly known, and there is much evidence [4] that Fuzzy logic can be very useful for predicting the path of chaotic systems.

Various chaotic controls can be found in the literature, many of which use small perturbations to guide the system [5] with applications such as controlling cardiac chaos [2] or an example where the techniques are used to control the well known chaotic Chua's circuit [3] without using feedback. There is also a lot of evidence that these techniques are also very effective in non-chaotic systems, see for example [1].

References

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