# Technical Brief No. 32

All Technical Briefs are based on past projects at RH Lyon Division

**Knitting**
**Needles**
**Stress Analysis**
**Finite Elements**

## *Fatigue in High Speed Machinery*

***Vibration dramatically reduces life expectancy***

***Abrupt accelerations result in failure***

Many machines, such as those involved in the clothing industry, produce product at a rate proportional to their speed. Sewing and knitting machines for example have cam driven components that have their positions defined by the cam shapes. The cams and followers may have been designed for displacement only, and the accelerations involved would have been acceptable at the original design speed. As the operating speed of the machine is increased, the accelerations increase accordingly, causing greater forces and resulting vibrations and the stresses they induce.

The accelerations can be very abrupt, having time constants 10 to 100 microseconds in duration because of cam profiles that look smooth to the eye, but may have discontinuities on slope or curvature that will excite higher modes of vibration of the knitting needle. Such sharp impulses excite resonances in the cam followers and in the components attached to them. The resonant vibration of the industrial knitting needle is excited by discontinuities of acceleration at its "butt" end, which is directly connected to the knitting machine cam groove. The “butt” is, in turn, excited by discontinuities of curvature in the cam profile. A resonance in the needle can cause breakage of the hook in the needle and a defect in the knitted product.

**How to……….**

**The fatigue analysis procedure consists of the following steps:**

1. **Determine component inputs from a geometric analysis or a dynamic simulation of the mechanism.**
2. **Carry out experimental tests to determine the high frequency modal dynamics of the part.**
3. **Develop a structural scale model.**
4. **Create a finite element model of the part and use the dynamical inputs to predict stress variations.**
5. **Use a fatigue model (an S-N curve) to predict fatigue life.**
6. **Modify the design (inputs or part parameters) to reduce stresses and increase the predicted life.**

***Experimental and analytical procedures used***

The methods of analysis for the knitting machine case are analogous to those that would be used in most other machines. They involve both experimental and analytical procedures and can be illustrated by the knitting needle example.

A experimental scale model of the knitting needle was made. Because of the small size of the needle, it was "scaled up" by a factor of 10:1, which means that the resonance frequencies in the model are reduced by the same factor of 10. Small parts are difficult to make vibration measurements on directly, but a scaled-up version of the part can have exciters and sensors directly attached so that resonance frequencies, mode shapes, and transfer functions can be determined. Such measurements can be useful in evaluating outputs from a parallel analytical study; for example, a finite element calculation.

The finite element calculation is valuable for predicting the vibrational response of machine components due to cam or other inputs. Displacements or accelerations can be compared with measurements, but the finite element model will also predict stresses that determine fatigue life. Standard models of fatigue life for the material as they are affected by the processing involved may not predict fatigue life precisely, but directions for design improvement can be derived from the calculations.

The fatigue and breakage of small parts in high speed machinery receives much attention in design and production quality assurance efforts. We have found this combination of analytical modeling, accompanied by experimental studies, to be highly effective in both determining the problem areas in the part and in recommending design changes.