References

1 Wilkes, D. F., "Rolamite: A New Mechanical Design Concept," Report SC-RR-67-656, Sandia Laboratory, 1967.

2 Wilkes, D. F., "Rolamite: A New Mechanism," *Mechanical Engineering*, Vol. 90, Number 4, April 1968, p. 17.

3 Shinkle, J. N., Sandia Laboratory, and Hornung, K. G., Ohio State University, private communication.

4 Cadman, R. V., "Rolamite—Geometry and Force Analysis," JOURNAL OF ENGINEERING FOR INDUSTRY, TRANS. ASME, Vol. 91, No. 1, Series B, Feb. 1969, pp. 185–191.

5 Wilkes, D. F., op. cit., p. 44 (reference [1]).

DISCUSSION

D. F. Wilkes[3]

Drs. Percival and Norwood have turned out an interesting addition to the available analytical and experimental tools for rolamite, and in addition, provided the useful function of turning attention to the need to better understand rolamite dynamics.

The derivation of a simplified equation of motion for basic rolamites from a very general Lagrange type equation is certainly a thorough and fundamental approach. By using generalized subscript notation, the equations can easily be extended to include more sophisticated rolamite devices embodying more than two rollers. One type of input which wasn't included but which certainly can come into play in a significant way under certain dynamic conditions, is that of difference in tensile strain in the straight portions of the band, and strain gradients (partially frictionally controlled) in the portion of the band in contact with the rollers which can be dynamically induced and which will perturb the more simple equations of motion.

The treatment of roller slippage in this paper is of course only valid if the rollers are frictionally constrained. The more normal situation in a dynamic rolamite mechanism where slippage is undesirable and motions limited, is to pin the rollers to the band. One further extension for future dynamic analyses should be in the field of loose rolamite behavior.

The writer is of the opinion that the general equations of motion should in the future break the nonconservative term down into the known types of dissipative contributions such as:

1 Hysteresis losses in the band and load zones,
2 Viscous friction due to viscous shear, squeeze film, inertial effects of the displaced fluid,
3 Coulomb friction due to asperity seating,
4 Plastic deformations of asperities, and
5 Adhesion of contacting materials.

In this way, by various experimental means, the relative behavior and magnitudes of these contributions may be separated out, allowing for a more accurate dynamic model of the nonconservative forces. Through such an understanding, substantial reductions in rolamite friction may still be available.

Tests were made to verify that viscous forces in the experiment were negligible, but that was for a system being accelerated by gravity; certainly at some velocity, viscous forces would loom large even in air, hence the conclusion that viscous forces in rolamite devices are not significant is not generally valid.

The fact that the dynamically deduced friction coefficients were even lower than those which were derived on the basis of quasi static measurements is indeed encouraging. Now that sufficiently accurate experimental means of breaking down rolamite deflection versus time behavior are available, mechanism designers can actually study, verify, and develop rolamite designs in more refined style.

Authors' Closure

The authors wish to thank Mr. Wilkes for his comments. Several points which he makes are indeed valid. The analytical approach "can easily be extended to include more sophisticated rolamite devices." For example, in the case where the tension is not uniform along the band, one writes the energy of tension as

$$V_t(x) - V_t(0) = \int_0^x T(x) \frac{d\delta}{dT} \frac{dT}{dx}\, dx,$$

where δ is the elongation and T is a given function of x. Similarly, when both the thickness and the width of the band vary along the length, the energy of bending becomes

$$V_b(x) - V_b(0) = \frac{E}{24a^2} \int_0^x [b(x)]^3\, W(x)\, dx,$$

where W is the total width of the band. When b and W are constant and there is a cutout of width $w(x)$, then the right side equals a constant minus V_c (V_c is defined just before equation (10)). Thus, the equation of motion can be easily altered to include many variations of the device.

The authors wish to point out that the importance of understanding slippage between the bank and rollers should not be overlooked. The determination of the need for additional mechanical constraint between the band and rollers, such as the pin which is suggested, must surely involve an understanding of the problem of kinematic tightness.

As is the case in many practical situations, the theory is limited by the lack of experimental information. In the present case, equations (1) through (11) were derived to explain the overall behavior of rolamite; then it was stated that experiments were needed to determine which effects in Mr. Wilkes' list would be more significant. The inclusion of more specific types of friction in the analytical description of the motion will be difficult. The total for all the various types of friction is very small in most rolamite devices. Greatly improved experimental arrangements will be required if one is to disentangle the various causes of friction. The problem of separation is further complicated by the fact that several of the causes which are listed are approximated by the same analytical model. The needed experiments represent a challenge in equipment design and a fruitful area for future study.

Professor T. R. Kane, Stanford University has brought to the authors' attention that the total moving weight defined in the sentence following equation (12) should include not only the rollers and the band on the rollers but a small portion of band of length l shown in Fig. 2. This portion of band will undergo effective translation with a corresponding decrease in potential energy due to the motion of the roller cluster in the vertical orientation. This small additional weight caused very little change in the results, less than 5 percent for the worst case, that of the thickest band. This is within the experimental error and no correction will be made in the results.

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