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INTELLIGENT MODELLING OF CONTACT MECHANICS AND FRICTION DYNAMICS

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EXTENDED ABSTRACT

This paper considers the investigations into adhesion, contact mechanics metal erosion effects, wear and tare as a result of the effects of frictional forces. Mechanical components rely on friction for the transformation and delivery of energy from point A to point B. This requires the knowledge of combined energies as well as their associated dynamic models and ancillary parameters. Adhesion, contact, friction and wear are major problems limiting both the fabrication yield and lifetime of any devices. Since it is the area of real contact, which determines the sliding friction, adhesion interaction may strongly affect the friction force even when no adhesion can be detected in a pull-off experiment. Therefore a good scientific dynamic modelling of friction forces is a prerequisite for the understanding and monitoring of friction adverse effect on mechanical systems for good maintenance purposes.

1.0 INTRODUCTION

Friction has many adverse aspects giving rise to control problems, such as static error. It is quite a complex non-linear phenomenon. A deep understanding and adequate representation of the complicated friction behaviour are quite necessary for precision motion control. The pneumatic positioning system is particularly sensitive to the non-linear friction effect, since the force generation sub-system is difficult to make stiff enough. [1], have reported a variable structure control technique that overcomes nonlinearities associated with a pneumatic system. Models have been developed to allow the system to be studied through simulation conditions. They have shown that the system nonlinearities are due to compressibility of the air, time delay due to the slow propagation of the air pressure waves, particularly at low speeds and associated large friction force. The authors thus have omitted the fluid dynamic terms and have used the resulting simplified system model to derive the control law, represented by the pressure difference across the piston. The motion of the actuator's piston has been taken to be influenced by the pressure difference across the piston and friction force. Furthermore, the friction force has been taken as composed of three components: static force, dynamic force and a viscous force.

2.0 METHODOLGY AND ALGORITHM DEVELOPMENT

Restricting attention to friction in mechanics, the friction dynamics include Coulomb plus viscous friction, the Stribeck velocity-friction curve, static friction, frictional memory and rising static friction. In this article, neuro-fuzzy friction models are utilized for identification and modelling of contact mechanics and friction dynamics. A more systematic investigation of the friction behaviour caused by sealing effect on pneumatic components was reported by [2 & 3]. These works show that friction depends on a number of factors including operating pressure, seal running speed on the cylinder barrel and rod, barrel material and surface roughness, seal dimensions and profile, seal material, lubrication conditions, cylinder distortion during assembly, operating temperatures of actuator components and the two chamber pressures.

2.1 Actuator friction dynamics

The cylinder and piston dynamics are governed by a standard Newtonian force balance equation i.e.

$$M\ddot{x} + b\dot{x} + K_s x + F_{friction} = A_r(P_r - P_{atm}) - A_b(P_b - P_{atm}) \qquad (1)$$

where: M represents the load mass, $\ddot{x}$ represents the actuator acceleration, $\dot{x}$ represents the actuator velocity, x represents valve spool position, actual control of the pneumatic system, b represents viscosity of the actuator fluid (air), K_s represents the actuator stiffness, $F_{friction}$. Represents hysteresis forces, A_b and A_r represent the areas on the left side and the right side of the pneumatic, P_d and P_u represent the down and up stream pressures of air, P_{atm} represents the atmospheric pressure. The main nonlinearities in equation (1) are the term $F_{friction}$. The model used in this research was developed by [4]. The model consists of a zero region velocity in which the friction provides sufficient force to counteract the pressure differential in the cylinder, provided the F_{stick}, static friction is not exceeded. The stick slip friction model can be illustrated further as shown in the Fig.1.

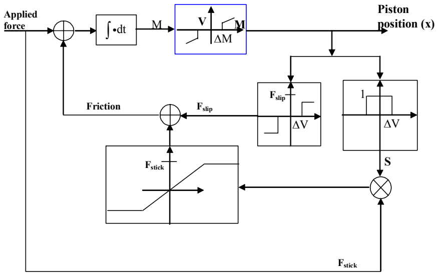


Figure 1 Complete stick-friction model

Where, ΔV represents the zero velocity region. M represents the momentum of the system. S represents the slip parameter (zero for no slip), and F_{slip} represents the sliding friction. The stick slip friction model can be further simplified to the diagram shown in Fig. 1. This simplified model implies that for small velocities (less than dv), the system is assumed to be stationary. The velocity required to move either the rotary vane or the linear piston is called the breakaway velocity (dv). Once dv is reached, the friction effects reduce to a sliding friction force, which is less than the static friction force. Investigations and an exact description of the relationship between pressure, volume, mass and temperature in the pneumatic cylinder chamber were given by [5]. Investigated and analysis of the thermodynamics of pneumatic cylinders were given by [6].

2.2 Modelling of pneumatic tribology hysteresis

Pneumatic servo control has long been an interesting topic for many researchers and engineers driven by the advantages of pneumatic actuators. Experimental NN-fuzzy training/testing data was sampled every 55 milliseconds. Pseudo random binary sequence signal was designed such that it excites all modes of the system. A record of 1000 samples was collected and used for identification. Fig. 2 shows the block diagram of the model.

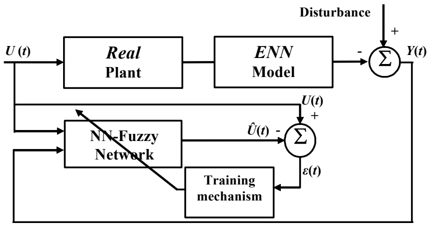
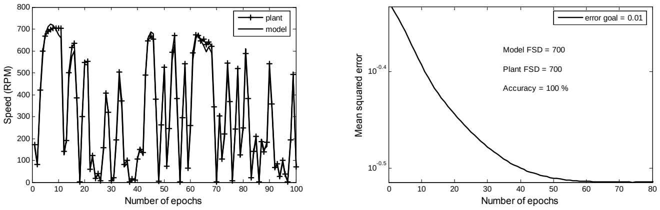


Figure 2 NARX model identification with ENN-Fuzzy

$U(t)$ represents input pressure and $e(t)$ white noise-generating sequence. $Y(t)$ represents partly an auto-regression term with extra inputs or exogenous variables and partly moving average term. Identification is a method of measuring a system's transfer function or some equivalent mathematical description from measurements of the system input and output. In system identification, a model of the system is estimated using measurements of the input and output of the system and implemented in MATLAB environment [7].

IMPLEMENTATION AND RESULTS

Network structure consists of Elman neural network and first order Sugeno with Gaussian membership functions. Two inputs fuzzifiers and a rule base of 14 rules with one output deffuzifier yielded network mean squared error prediction output of 0.0156545 in less than 100 epochs. As shown in Fig. 3.



a) Actual and predicted output **b) Mean squared error**

Figure 3 Modelling using ENN-fuzzy

All correlation test functions were within the 95% confidence intervals indicating adequate fitted model [8].

CONCLUSION

Neglecting hysteresis effects when modelling dynamic effects of friction due to adhesion and contact of mechanical component may lead to reduced life cycle of equipment. The results may breed a plethora of inaccuracies rendering unsafe and uneconomic viability of the component. Intelligent based modelling techniques are a good alternative to conventional techniques for accurate modelling of non-linear friction dynamics.

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