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automotive front end accessory belt drive systems employ multi ribbed serpentine belt and are subjected to crankshaft torque fluctuation component loading and dynamic environments which will affect the fatigue life of the belt the onset of catastrophic belt failure occurs in accessory drive systems when the rubber cracks or internal cords loose their resilience and become brittle this limits the durability performance of automotive front end accessory belt drives a new fatigue life model for predicting accessory belt lives subjected to various loading is developed in this study the stress life approach is employed to create the belt life equation where serpentine belt rib stresses are used as the damage parameter the multi axial state of stress in the belt rib tip is related to an equivalent uniaxial stress by employing the sines method and the total mean stresses are derived using the individual mean and the fluctuating stresses as in sines method to simulate the stress state between the v ribbed belt pulley two dimensional and three dimensional finite element models were built in order to study the stress distribution in the ribs of the belt the results obtained from the finite element fe belt model correlates well with the measured strain results which therefore validates the fe belt model and the stresses due to belt pre tension power transmission bending and radial compression are computed using the correlated finite element model the fatigue index b and the fatigue strength coefficient 6f are estimated empirically for the serpentine belt via experimental results the validity of belt fatigue model is confirmed via additional experimental results obtained from a variety of different accessory drive configuration using different loading profiles finally actual vehicle measured data is used to predict the belt life using this belt fatigue model dynamic analysis of a serpentine belt drive system with friction type automatic tensioner is performed and a closed form analytical solution is found for the first time for the sinusoidal input a sampling technique is employed to obtain discrete simulated load distribution for the components and the belt life distribution is predicted using this method

serpentine belt drive systems are widely used in automobiles due to their compactness and long life these systems are composed of a belt a driving pulley driven pulleys and a spring loaded tensioner the driven pulleys may include such accessories as the alternator air conditioner or power steering pump serpentine belt drives experience many different types of steady state motions and transient vibrations due to the different parameters in the system as a result of this it is important to create a mathematical model that allows the designer to extract information about the system such as the natural frequency and the mode shapes the accuracy of the model will depend primarily on the assumptions used in particular a key assumption is whether transverse and rotational motions of the belt are coupled due to the motion of the automatic belt tensioner this coupling is often neglected by authors who model only longitudinal belt response and in effect decouple the transverse and rotational motions using a solution based upon coupled motion as well as a solution employing rotational motion only the importance of this coupling will be assessed both solution results will be compared against published experimental data in addition a parametric study will be performed to determine the ability of the coupled and decoupled models to accurately predict changes in system natural frequencies and mode shapes due to changes in system parameters abstract

abstract belt vibration and slip are primary concerns in the design of serpentine belt drives belt pulley coupling is essential for the analysis this work investigates issues to advance the understanding of belt pulley mechanics closed form eigensolution approximations for an axially moving beam with small bending stiffness are given this model is the first order approximation for the transverse vibration of each span in a serpentine belt drive perturbation techniques for algebraic equations and the phase closure principle are used the eigensolutions are interpreted in terms of propagating waves for a complete serpentine belt drive a hybrid continuous discrete model is built incorporation of belt bending stiffness introduces linear belt pulley coupling this model can explain the transverse span vibrations caused by crankshaft pulley fluctuations at low engine idle speeds where other coupling mechanisms do not for the steady state analysis a novel transformation of the governing equations to a standard ode form for general purpose bvp solvers leads to numerically exact steady solutions a closed form singular perturbation solution is developed for the small bending stiffness case a coupling indicator based on the steady state is defined to quantify the undesirable belt pulley coupling a spatial discretization is developed to find the free vibration eigensolutions in contrast to prior formulations this discretization is numerically robust and free of missing false natural frequency concerns new dynamic properties induced by bending stiffness are characterized dynamic response calculations using the discretized model follow naturally the effects of major design variables are investigated this provides knowledge to help optimize structural design especially to reduce large belt transverse vibration finally to better predict the belt pulley contact interactions applicable to serpentine belt drives an improved model is established for the steady state mechanics bending stiffness is considered while other factors in the literature such as belt pulley friction and belt inertia are retained an iterative solution based on general purpose bvp solvers is presented to determine the belt deflections and the distributions of speed tension and friction along the belt as well as the belt pulley contact points and adhesion slip zones on the pulleys key design criteria like maximum transmissible moment and power efficiency are examined

this thesis is devoted to accurately modeling and analyzing the dynamic behavior of damped serpentine belt drive systems a viscoelastic moving material model is proposed to describe the transverse vibration of belt spans and a hybrid continuous discrete components viscoelastic system is proposed to represent the dynamics of the entire serpentine belt drive the direct multiple scales method is applied to the nonlinear vibration analysis of free forced and parametric vibration of viscoelastic moving belts nonlinear natural frequencies and near modal nonlinear response of free vibration of viscoelastic moving belts are obtained in closed form the amplitude of near and exact resonant response is predicted for viscoelastic moving belts excited by the eccentricity of pulleys closed form solutions of response amplitudes existence conditions and stability conditions of limit cycles are derived for parametrically excited viscoelastic moving belts block by block numerical integration method together with a galerkin discretization using travelling eigenfunctions is proposed to calculate the transient response of moving belts with general viscoelasticity an explicit exact characteristic equation of eigenvalues for undamped hybrid serpentine belt drives is derived which could provide insight into effects of design parameters on the frequency spectrum of the system a complex modal analysis method is developed for linear vibration analysis of non self adjoint hybrid serpentine belt drive systems for the first time the adjoint eigenfunction can be conveniently determined from the proposed auxiliary system nonlinear vibrations of viscoelastic and elastic hybrid serpentine belt drive systems are analyzed using the discretization multiple scales method for the first time this provides a basic understanding of parametric excitation threshold levels and the existence of multiple limit cycles the direct multiple scales method is developed for the nonlinear analysis of elastic hybrid serpentine belt drive systems comparisons between the direct multiple scale method and the discretization multiple scales help better understand the relationship between the two approaches

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