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7. Conclusions

This paper investigates the nonlinear dynamic behavior of a planetary gear system with equally spaced planets. The effect of mesh frequency is evaluated and the system behavior at different rotational velocities is examined; this may helps designers to understand how velocity can affect dynamic response of a planetary gear system. The main results are summarized below.

Modes corresponding to multiples of mesh frequency can be excited due to: i) the presence of higher harmonics of mesh stiffness variation; ii) nonlinear superharmonic resonance. Moreover, the resonance peaks lean-to the left, implying softening nonlinearity induced by teeth separation.

Comparing the presents results with those of the work of Ambarisha and Parker Ref.[2] shows that there are additional resonance peaks below 1600 Hz, ≅1800 Hz (the first distinct mode) and ≅8000 Hz. These peaks are the due to a combination of effects: i) the parametric instability from higher harmonics of mesh stiffness; ii) nonlinear subharmonic and superharmonic resonances of the first and second distinct modes.

Reducing the translational bearing stiffnesses generally cause decreasing the natural frequency as we expect from elementary considerations. Moreover, changing the bearing stiffness can influence the ratios between modes and, for certain values, produce additional internal resonances; this is reflected in a higher modal interaction in nonlinear regimes.

Different nonlinear phenomena such as nonlinear jumps, chaotic motions, and period-doubling bifurcations occur when the mesh frequency or any of its higher harmonics are near a natural frequency of the system. The nonlinearity is due to teeth separation that take place when the amplitude of vibration generates inertia forces exceeding the static preload.

The occurrence of a parametric instability is found when the rotational speed is twice the resonance of a rotational mode; this phenomenon is typical of almost all gearboxes.

In presence of internal resonances remarkable changes is observed; in particular, the variation of the bearing stiffness can greatly influence and enrich the dynamic scenario.

One of the most interesting disclosures of this work is related to the chaos-induced-imbalance; i.e. due to the symmetry of the system there is a perfect force balance, this means that the sun bearings are subjected to negligible forces (theoretically zero), this is

true in principle both in linear and nonlinear regular vibrations. However, when the vibration is chaotic, the system experiences a symmetry breaking, a well known phenomenon in chaotic dynamics. This symmetry breaking in the response has an important counterpart in the mechanical behavior of the system, i.e. it generates unexpected and undesirable loads on the sun supports. This aspect of the system dynamics cannot be accounted for using the classical design tools, leading to possibility of new failure modes.

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