INVESTIGATION OF VIBRATIONS IN ELEVATOR STRUCTURES UNDER DYNAMIC LOADING

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Annotation. *This thesis investigates vibrations in elevator structures under dynamic loading. Start-up, acceleration, and braking generate dynamic forces that affect structural vibration. The study focuses on the effects of mass, stiffness, natural frequencies, and guide-rail properties on dynamic response. Finite element and modal analyses are considered effective methods for evaluating elevator vibration and improving safety and ride comfort.*

Keywords: *elevator structure, dynamic loading, vibration, natural frequency, modal analysis, finite element method, guide rail, ANSYS.*

Аннотация. *В настоящей работе исследуются вибрации в конструкциях лифтов под воздействием динамических нагрузок. Пуск, ускорение и торможение лифта вызывают динамические силы, влияющие на вибрационное состояние конструкции. Основное внимание уделено влиянию массы, жесткости, собственных частот и характеристик направляющих рельсов на динамический отклик. Метод конечных элементов и модальный анализ рассматриваются как эффективные методы оценки вибраций лифта, повышения его безопасности и обеспечения комфорта пассажиров.*

Ключевые слова: *конструкция лифта, динамическая нагрузка, вибрация, собственная частота, модальный анализ, метод конечных элементов, направляющий рельс, ANSYS.*

Annotatsiya. *Ushbu ishda lift konstruksiyalarining dinamik yuklanish ta'siridagi tebranishlari tadqiq etilgan. Liftning ishga tushishi, tezlanishi va tormozlanishi konstruksiyaning tebranish holatiga ta'sir qiluvchi dinamik kuchlarni yuzaga keltiradi. Tadqiqotda massa, qattiqlik, tabiiy chastotalar va yo'naltiruvchi relslarning xususiyatlarining dinamik javobga ta'siriga asosiy e'tibor qaratilgan. Chekli elementlar usuli va modal tahlil lift tebranishlarini baholash, xavfsizlikni oshirish hamda yo'lovchilar uchun qulaylikni ta'minlashning samarali usullari sifatida ko'rib chiqilgan.*

Kalit so'zlar: *lift konstruksiyasi, dinamik yuklanish, tebranish, tabiiy chastota, modal tahlil, chekli elementlar usuli, yo'naltiruvchi rels, ANSYS.*

Introduction. Modern high-speed elevators are complex mechanical systems in which the elevator car, guide rails, guide shoes, ropes, counterweight, and supporting structures interact dynamically. During acceleration and braking, changes in velocity generate inertial forces that influence the dynamic response of the elevator system. Salamaliki-Simpson and Kaczmarczyk noted that dynamic excitation in lift systems can result from acceleration and deceleration, building sway, drive-machine effects, and car-guide-rail interaction [1]. The interaction between the elevator car and guide rails is particularly important for vibration analysis. Zhang developed a coupled guide rail–guide shoe–car model and showed that structural parameters of the guide system significantly influence the dynamic characteristics of an elevator [2]. Similarly, Nakao demonstrated that periodic variations in guide-rail stiffness can produce parametric vibration of the elevator car, particularly when the excitation frequency approaches specific relationships with the natural frequency of the car [3].

For high-speed elevators, guide-rail irregularities are another important source of vibration. According to Song, the stiffness of guide shoes, guide-rail straightness, cabin parameters, and excitation characteristics all affect the horizontal vibration response of the elevator cabin [4]. Qin, Zhang, and Jing further reported that wind-induced deformation of high-rise buildings can be transmitted to elevator guide rails and subsequently influence elevator-car vibration [5]. Therefore, determining the natural frequencies and mode shapes of an elevator structure is essential for evaluating its dynamic behavior. Kobayashi used operational modal analysis to identify the modal parameters and estimate stiffness characteristics of an elevator car from experimentally obtained natural frequencies and mode shapes [6].

Methodology. The finite element method (FEM) can be applied to investigate the dynamic characteristics of elevator structures. In a numerical model, the elevator frame, guide rails, cabin, and supporting components are represented by appropriate finite elements. Material properties, structural mass, stiffness, and boundary conditions are then assigned to the model. Modal analysis is used to determine the natural frequencies and corresponding mode shapes of the structure. The fundamental eigenvalue equation can be expressed as:

$$[K]\{\varphi\} = \omega^2[M]\{\varphi\}$$

where [K] is the stiffness matrix, [M] is the mass matrix, {φ} represents the mode shape, and ω is the natural angular frequency.

The natural frequency is obtained from:

$$f = \omega / 2\pi$$

The simplified relationship

$$f_n = 1/(2\pi)\sqrt{(k/m)}$$

shows that an increase in structural stiffness generally increases the natural frequency, whereas an increase in mass decreases it.

Results and discussion. The reviewed studies demonstrate that elevator vibration is influenced by several interconnected parameters. In particular, guide-rail stiffness and irregularity can significantly affect horizontal vibration. Song showed that reducing guide-rail straightness errors and optimizing guide-shoe stiffness can decrease the vibration response of the elevator cabin [4]. The results indicate that periodic changes in guide-rail stiffness may cause considerable vibration when the excitation condition approaches the natural frequency of the elevator car.

Conclusion. The investigation demonstrates that dynamic loading significantly affects the vibration behavior of elevator structures. Acceleration, braking, guide-rail irregularities, structural stiffness, mass, and external excitation can contribute to elevator vibration. The reviewed research confirms that the car–guide shoe–guide rail interaction is one of the important factors governing elevator dynamic response. Modal analysis and the finite element method provide effective tools for determining natural frequencies, mode shapes, and critical vibration characteristics. Proper optimization of stiffness, mass, guide-rail properties, and damping can reduce vibration, avoid resonance, and improve the safety and ride comfort of elevator systems.

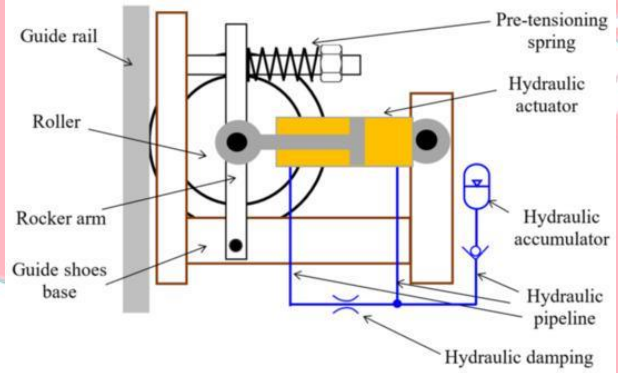


Figure 1. Coupled dynamic model of an elevator cabin, guide shoes, and guide rails

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