Structural Design and Analysis of Self Propelled Device for Vehicles

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***Abstract*— Optimal planning of space for parking of vehicles is order of the day which means more number of vehicles needs to be parked at limited place. If two vehicles can be parked in a place (One over another without touching each other) which is actually meant for one vehicle earlier mentioned constraint can be superseded successfully. Design of such aid is planned through this work. It is named as self propelled device for the reason that it raises the vehicle by accelerating the same vehicle without demanding for external means. The intended system incorporates mechanical means without employing conventional hydraulic means there by it eliminates leakage issues associated and other maintenance aspects. This work aims at design of such system which operates just by running the vehicle in standstill condition. The proposed system will have friction wheels which will get engaged with vehicle for getting energized by running the same vehicle. The intended design will also have bevel gearing, lead screw mechanism, etc. To start with all the subsystems of the proposed design are identified and each of them is designed for getting their dimensions. Then these dimensional models are transformed to solid model of the assembled configuration using 3D CAD software. Functional load which will be experienced by this design is assessed and structural analysis is carried out against these loads using Finite Element Method (FEM) in commercial FEA software i.e. ANSYS**.

Keywords*— *Designed model, Self propelled device, FEA, Modal analysis.

I. INTRODUCTION

Confined space available for parking vehicles is the burning problem particularly in places like malls which attracts huge gathering. Accommodating more vehicles in such limited space will give sigh of relief to overcome above said problem. Parking vehicles in modular configuration (One over other) would be a promising solution. Many such modular systems are available (Of course may be in overseas) as shown in Fig. 1.

Fig. 1. Modular mode of parking

Primary disadvantages of such systems are that they need external power for lifting the vehicle and one dedicated manpower to do so. Hence it is decided to explore for a mechanism which derives power from the same vehicle that needs to be lifted and doesn't call for any third person by enabling the pilot of the vehicle himself to do so.

Metropolitan towns strongly need latest parking systems, giving drivers with parking information. Existing parking systems normally neglect the parking price issue and do not automatically give optimal car parks meeting drivers' demand. Presently, the parking price has no negotiable place; consumers lose their bargaining place to obtain better and cost effective parking [1]. A system works on hydraulic drive which comprises of three main parts: hydraulic pump, driven by an electric motor, hydraulic cylinder to elevate the vehicle. The hydraulic jacks drive independently separately for either side of car as per the breakdown situation. The car gets elevated and load gets distributed on three point i.e., ram of hydraulic cylinder and two tires opposite to side which is elevated. This jack will be very useful for all the old people and especially for ladies who find it extremely tough to operate the jack manually in any breakdown condition. The motive behind using hydraulic system instead of a pneumatic system is the more power generated by the system and simple in design when compared to a pneumatic design. As the hydraulic oil is incompressible so the raising capacity is more in comparison with the pneumatic system which works on air which is compressible [2]. A multi-robot system for independent vehicle extraction and transportation is presented. The fabricated prototype is capable to pick vehicles from limited spaces with delicate handling, swiftly and in any direction. The novel lifting robots are able to have omnidirectional movement, thus they can under-ride the targeted vehicle and port to its wheels for a synchronized lifting and picking up [3]. A scaled down working model of a car parking system for parking 6 to 24 cars within a parking area of 32.17 m² is designed and developed. The chain and sprocket mechanism is used for driving the parking structure and a one fourth HP brake motor is used for energizing the system and indexing the platform. The platform is realized to match the working model [4]. A concept for the automation of lift car operations on high elevation building construction sites, in order to build high elevation building efficiently and make a proper elevating plan is discussed. It started with a hand-operated lift car, and graduated to automatic lift car [5]. Smart Parking Systems get information about available parking spaces, process it and then position the car at a certain place. A prototype of the parking aid system based on the proposed architecture was developed here. The implemented hardware, software, and implementation solutions in this prototype configuration are described in this paper. The effective circular design is presented here having rack-pinion special arrangement which is used to lift and position the car in the certain position. The design of rack pinion mechanism is also replicated using COMSOL software [6].

As can be seen, all the research focus on design of most complicated systems. Further it is also noticed that all the systems are having either hydraulic or pneumatic means and hence costlier. Moreover they demand more power for themselves and also their maintenance is tedious.

Based on the limitations brought out as an outcome of literature review it is observed that a great need exists for development of self-propelled device for parking vehicles one over other.

II. DESIGN PHILOSOPHY

Hence it is planned to design a self-propelled device so as to lift vehicles from floor to elevated height. Complexity associated with this requirement is mechanism which imparts self-lifting capability is needed. Further it should take power aid from vehicle which needs to be elevated itself without any external source. Proposed design with all subsystems is shown in Fig. 2.

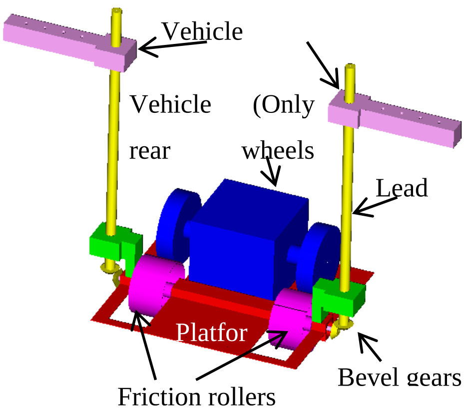

Fig. 2. Proposed design

To start with vehicle interface connects to vehicle. Then vehicle gets on platform with its base touching platform, front wheel hang in air and rear wheels engage with roller. Then vehicle engine will start and wheels rotate and hence rotate friction rollers. Motion of rollers transmit to lead screw through bevel gears. As lead screw rotates whole platform along with vehicle lifts while nut remains stationary.

From the above figure the following components are identified for which detailed design is carried out.

- Lead screw
- Friction rollers
- Platform
- Bevel gears
- Shaft
- Bearing

III. DESIGN CONFIGURATION

Following design inputs are considered.

- Torque = 7.89 N-m
- Speed of engine = 7500 rpm
- Tire width = 90 mm
- Coefficient of friction between tire and road = 0.7
- Surface roughness = 6.3 S

Outcome of design is summarized in Table 1.

Table 1: Design parameters

Sl. No.	Design Parameter	Value
Lead Screw		
1.	Diameter	53 mm
2.	Length	1000 mm
Friction roller		
1.	Diameter	300 mm
2.	Width	180 mm
3.	Rim thickness	3 mm
Platform		
1.	Overall length	1000 mm
2.	Width	1100 mm
Bevel gear		
1.	Size	100 mm
2.	Number of teeth	50
Shaft		
1.	Diameter	25 mm
2.	Length	1152 mm
Bearing		
1.	Outer diameter	80 mm
2.	Width	21 mm
3.	Designation	6405

IV. STRUCTURAL ANALYSIS

Structural analysis of self-propelled device is carried out using Finite Element Method (FEM) in ANSYS software in order to assess the design adequacy against the functional load. Maximum Von Misses stress thus obtained is compared with allowable stress and obtained the available factor of safety.

A. Criteria

(a) Static analysis

- Minimum available factor of safety should be more than the desired factor of safety (1.5).

(b) Modal analysis

- First natural frequency should not coincide with frequency associated with operating condition of shaft i.e. 80 Hz (4850 rpm).

To begin with geometric model of the intended design is built in 3D CAD software from its dimensions. However load bearing members are only considered for analysis. Then geometric model is converted into FE model by discretizing platform with shell (SHELL63) elements, friction roller & shaft with beam (BEAM4) elements. Vehicle mass has been smeared in FE model of platform. As all the subsystems are made of steel its material properties are considered for the analysis. Shaft ends are constrained for all DOF while limiting Y-translation to the specified value.

FE model with boundary conditions is shown in Fig. 3.

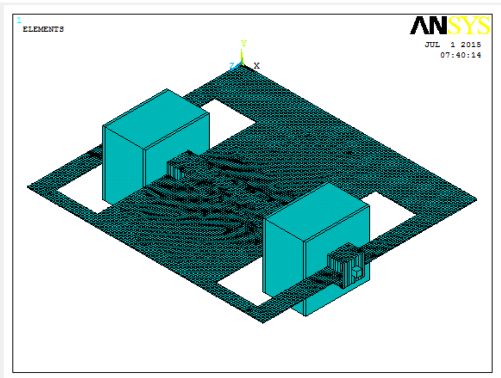

Fig. 3. FE model

Static analysis was carried out and the corresponding Von Misses stress plot is shown in Fig. 4.

Von misses stress = 152MPa

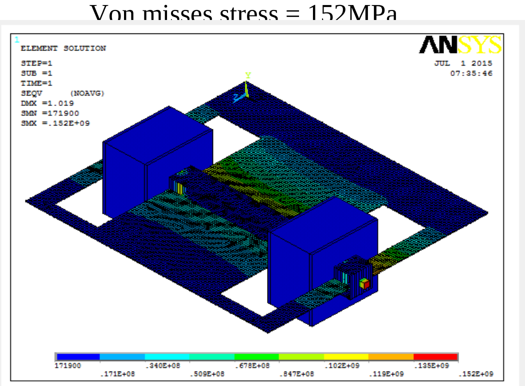

Fig.4. Stress plot

Then dynamic (Modal) analysis was also carried out.

Modal analysis is the study of the dynamic properties of structures under vibration excitation. In structural engineering, modal analysis uses a structure's overall mass and stiffness to find the various periods that it will naturally resonate at. A modal analysis calculates the undamped natural modes of a system. These modes are given in decreasing order of period and are numbered starting from 1. Mode shape plot corresponding to first natural frequency is shown in Fig. 5.

First Natural Frequency = 5.78 Hz

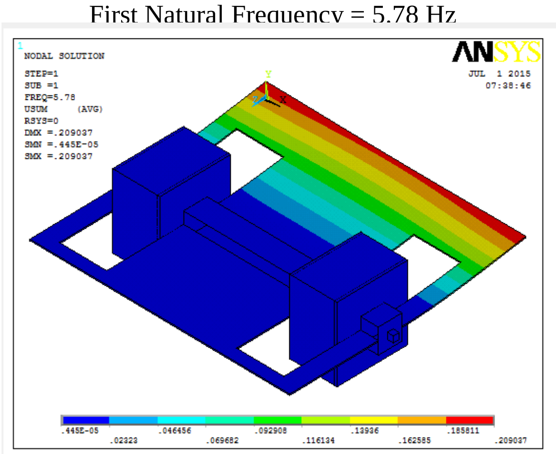

Fig. 5. Mode shape plot

V. RESULTS AND DISCUSSIONS

Outcome of analyses is summarized in Table 2.

Table 2: Analyses results

Sl. No.	Result	Maximum Value	Allowable value	Factor of safety
Static				
1.	Von Misses stress	152 MPa	330MPa	2.17
Modal				
2.	First natural frequency	5.78 Hz	Critical value: 80 Hz	--

- Available factor of safety is observed to be 2.17 which is more than minimum desired factor of safety (1.5). Hence the design is safe.
- System doesn't experience resonance.

VI. CONCLUSIONS

A self-propelled device is designed so as to lift vehicles from floor to elevated height. As the available factor of safety is more than minimum desired factor of safety the design is safe and system doesn't experience resonance.

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