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Design Evolution of Drive Booster Configuration for Terrain Vehicles

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ABSTRACT:

This paper presents the design evolution of drive booster configuration for terrain vehicle to manoeuvre over the roads covered with mud or snow. The proposed design of booster consisted small number of parts whose sizing is accomplished through design calculations. The intended system will take power from engine to do so but in petite proportion. The booster increases the moment of inertia through increment in angular speed of terrain vehicle. Structural design adequacy is assessed using ANSYS commercial finite element analysis software. Available safety margin is extracted through static analysis. The severance of first natural frequency of the intended booster system is ascertained from that of engine by carrying out modal analysis.

KEYWORDS:

Terrain vehicle; Structural design; Drive booster; Static analysis; Modal analysis

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1. Introduction

Terrain vehicles spend hard efforts while climbing over roads full of snow or mud as it would be a discouraging situation to cope up with excess energy demand necessary to push the vehicle ahead. In such situation engine needs additional aid in terms of energy. Conventional vehicle configuration results into derivation of higher speed instead of energy at the cost of additional consumption of fuel. Hence a great demand exists for a device to be installed in terrain vehicle which provides excess energy as per demand. Wierzczyk [1] mentions in his work that the IC engine concept did not alter much except most of the work done on investigating better materials with regard to improved fatigue life and weight optimization so as to minimize inertial forces. Heavy engines are evolved now and then and almost all of them are of 'V' type construction of cylinders and pistons for simpler erection. Typical vehicles like sports cars are built with boxer-type piston-crank systems. Recent years brought out the piercing of latest engine configurations with VR or V-VR piston-crank systems which are often called as W engines due to a distinctive orientation of the connecting rod. The V-VR crankshaft-piston arrangement provides design of engines having features like high displacement and reduced size for simpler installation in the vehicle's engine partition and these types of configurations are often considered in high class vehicles.

Rakopoulos et al [2] presented working of an indirect injection, naturally aspirated, diesel engine under unsteady conditions due to abrupt increase in load. For this requirement, a single-zone thermodynamic model which takes into account of all subsystems by following the filling and emptying modelling technique is presented along with the dynamic model of the engine with particular subsystems to sculpt the upkeep of energy in the crankshaft, the inertia forces, the governor dynamics and the fuel pump characteristics. Rakopoulos ea al [3] worked out computer based analysis for analyzing the energy and concert of a turbocharged diesel engine that is working under unsteady load conditions. The representation includes many new issues such as elaborated study of mechanical friction, exclusive thought for the stages of each cylinder during a cycle and theoretical modeling of the fuel pump. This model has been checked with laboratory testing of a turbocharged diesel engine that was energized under unsteady conditions.

Mikalsen et al [4] studied the evolution of typical IC engines, from air compressors came in mid of 20th century to current hydraulic engines and linear electric generators. Sole attributes of the typical engine are brought out and their influence on working of engine is presented, along with salient merits and demerits in contrast with usual engines. The paper concentrated chiefly on urbanized engines having data associated with its working. Jaroszczyk et al [5] discussed the filter concert of high dust holding capacity engine air filters. Filter specifications, design and performance were mentioned in elaborated sense. Working properties of the media and full size filters were extracted using on-line particle counters and the gravimetric test method. Initial and final efficiency and dust loading performance attributes were given. Ivanov et al [6] presented a new methodological approach for the development of torque vectoring control systems for all-terrain electric ground vehicles. The above discussion reveals that there is no much focus on the burning problem of terrain vehicles. In this paper, design of drive booster is proposed which will be sensitive to energy demand through speed increment and accordingly increases moment of inertia and hence energy. Section 2 presents the details of design philosophy. Section 3 discusses the structural analyses and their results followed by conclusions.

2. Design philosophy

Engine puts up more endeavours when a terrain vehicle has to pass over adverse conditions road covered with snow. This effort will be in terms of feeding more fuel to engine so as to gain more energy to push the vehicle. Ultimately this will be resulting in raising the speed of engine but not energy. Hence a novel device called driver booster is proposed in this work which will increase the energy with increasing speed of engine by increasing moment of inertia. Unique feature of the proposed design is sensitiveness of moment of inertia with that of speed of engine. Proposed design with all subsystems is shown in Fig. 1. The proposed design consists of a shaft which will be connected to two hubs on extreme ends. Top hub will be connected to shaft rigidly whereas bottom hub will be connected to shaft such a way that it rotates along with the shaft but it can slide up and down relative to shaft.

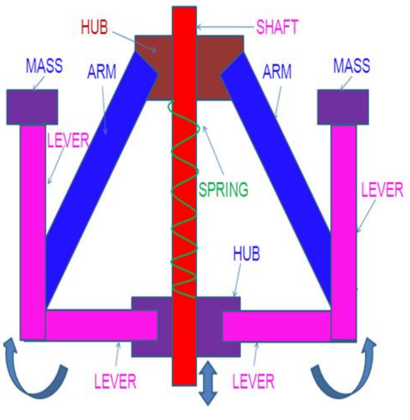

Fig. 1: Proposed design of drive booster

A spring will be connected between top and bottom hubs. Two arms connect the top hub to levers through pivot which will be extended from the bottom hub. Lever will be in L-shape bottom part of which will be connected to bottom hub and top part will house a mass positioned on its top. This lever can pivot such that mass comes close or goes away from shaft axis. In acceleration phase starts with engine shaft speed and the angular velocity increases. Due to this centrifugal force dominates spring force and accordingly spring compresses. Then arms rotate through the levers followed by pull-up of masses through angular motion. Further bottom hub moves up towards top hub and the moment of inertia increases. Finally, engine receives the desired amount of high energy. The following design inputs with regard to a typical terrain vehicle are considered:

- Minimum speed = 2175 rpm.
- Maximum speed = 4000 rpm.
- Rated speed = 3087 rpm.
- Time taken to attain maximum speed = 60 sec.
- Mass positioned on lever = 730 g.

Outcome of design is summarized in Table 1. Final design configuration is shown in Fig. 2.

Table 1: Design parameters

Item	Parameter	Value
Configuration	Minimum energy	2.43×10^5 J
	Maximum energy	1.5×10^6 J
Spring	Wire diameter	25 mm
	Mean coil diameter	507 mm
	Number of turns	16
	Free length	1860 mm
Shaft	Outer diameter	380 mm
	Length	3734 mm
Hub	Outer diameter	760 mm
	Inner diameter	380 mm
Arm	Cross-section	Circular
	Size	276 mm
	Length	4000 mm
Lever	Cross-section	Circular
	Size	276 mm
Bearing	Outer diameter	480 mm
	Width	46 mm
	Designation	61876 MA

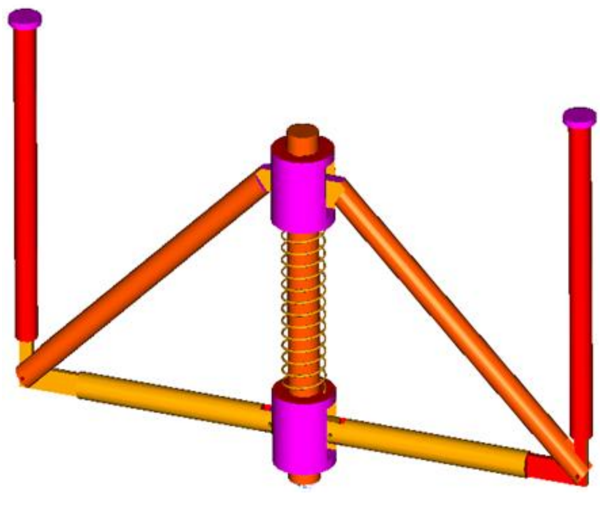

Fig. 2: Solid model of the assembly

3. Structural analysis

The objective of the structural analysis is to assess the design adequacy against the functional load and to validate the design calculations. To begin with geometric model of the intended design is built in 3D CAD software from its dimensions. Load bearing members are only considered for analysis. Then geometric model is converted into finite element (FE) model by discretizing with linear beam (BEAM4) elements in ANSYS commercial FE analysis software. As all sub systems of drive booster are made of steel, its material properties are considered for the analysis. Both extreme sides of the shaft are constrained in all degrees of freedom except the rotation about shaft axis.

Structural analysis is carried out against the self weight and functional loads due to movement of the system. Modal analysis is also carried out. Von Mises stress plot and first natural frequency mode shape plot are shown in Figs. 3 and 4 respectively. Maximum Von Mises stress is observed to be 67 MPa. Available factor of safety is observed to be 4.9 by comparing the maximum stress with that of allowable yield strength of steel material as 330 MPa. As the available factor of safety (4.9) is more than minimum desired factor of safety (1.5), the design is safe. Frequency of the intended system corresponding to first bending mode is found to be 38 Hz. As the first natural frequency (38 Hz) is much above the frequency associated with operating speed of engine (36.25 Hz, 2175 rpm), the drive booster system doesn't experience resonance with engine.

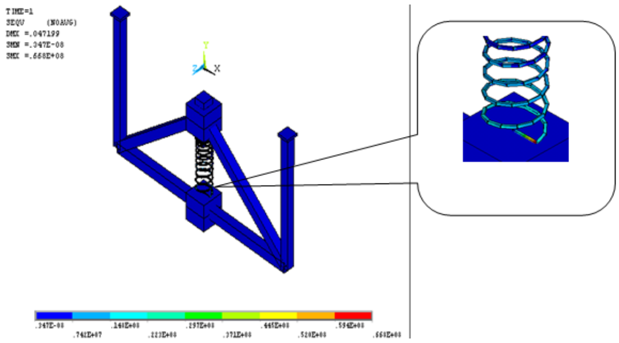

Fig. 3: Von mises stress plot (max stress = 67 MPa)

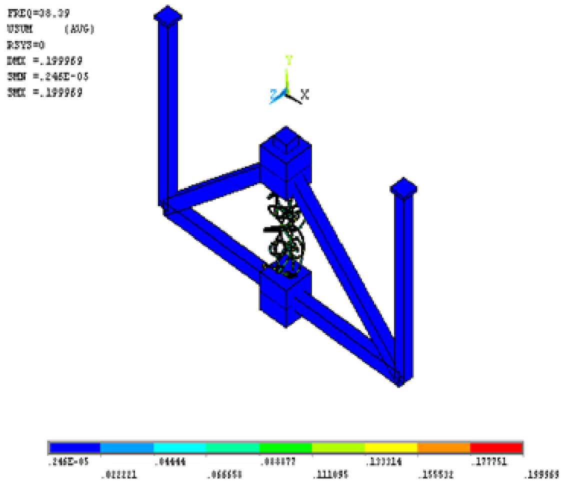

Fig. 4: First natural frequency (bending mode 38 Hz)

4. Conclusions

Novel design of drive booster is evolved in this work which is meant for enhancing the energy with increasing speed of engine by increasing moment of inertia. Design adequacy of the configuration is assessed using finite element analysis and verified that the proposed booster design is safe. Further work can be directed towards testing and correlating the test results with simulation to implement the evolved design into production.

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