COMPUTER-AIDED SIMULATION AND OPTIMISATION OF ROAD VEHICLE SUSPENSION SYSTEMS

by

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Abstract

Problems were experienced during the development of a military three-axle vehicle weighing 22 tons. These problems included premature axle and suspension failures. In trying to solve these problems full three-dimensional parametric studies were performed using commercially available computer-aided vehicle dynamic simulation programs. Performing these parametric simulation studies proved to be a cumbersome task. The need for a computationally economic computer-aided simulation program coupled to a systematic optimisation process for the optimisation of the vehicle's suspension system therefore arose.

After the presentation of an overview of relevant work that has been done in the field of suspension optimisation, this study continues with the development of a two-dimensional multi-body vehicle dynamics simulation program that is to be linked to a robust mathematical optimisation algorithm. The optimisation algorithm selected is the gradient based LFOPC algorithm for constrained optimisation. With this algorithm the design space can be systematically searched for a set of design variables that optimises the suspension system with respect to ride-comfort.

For the above purposes a two-dimensional vehicle dynamics simulation program Vehsim2d is developed here. In order to enable the optimisation of non-linear suspension characteristics, a six piece-wise continuous linear approximation is used for representing spring, damper, bump stop, tyre stiffness and tyre damping characteristics. With this approach twelve design variables are used to describe the characteristic of each of the suspension components. The simulation results of the Vehsim2d program are qualified by comparing them with that of the more advanced DADS program and by comparison with experimentally measured values on a real military vehicle.

A comprehensive case study is presented in which the damper characteristics for the three axle military vehicle is optimised. Three different route profiles are selected as representative terrain over which the vehicle is to prove its mobility. One of the road profiles used is a dirt road profile of length 2.2 km and is specifically selected because the major suspension failures on the vehicle occurred on similar road profiles. An objectively determined ride-comfort value at the driver, centre of gravity, rear passenger and for pitch movement of the vehicle is used as the objective function for the optimisation. From the optimisation results an improvement of up to 40% in ride-comfort is obtained. These results were again qualified by means of DADS simulations.

In conclusion this study proves that the Vehsim2D/LFOPC modelling and optimisation system is a valuable tool for vehicle designers.

Keywords: *vehicle suspension optimisation, passive suspension, mathematical programming, gradient based optimisation algorithm, two-dimensional vehicle model*

REKENAARGESTEUNDE SIMULASIE EN OPTIMERING VAN PADVOERTUIG SUSPENSIESTELSELS

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Samevatting

Probleme is tydens die ontwikkeling van 'n drie-as militêre voertuig, met massa 22 ton, ondervind. Die probleme het onder andere vroeë faling van die voertuig aste en suspensiekomponente ingesluit. Tydens pogings om hierdie probleme op te los, is volle drie dimensionele parametriese studies met kommersieël beskikbare voertuig dinamika simulasie pakkette uitgevoer. Die uitvoer van hierdie parametriese studies was omslagtig. Die behoefte aan 'n numeries ekonomiese rekenaargesteunde simulasie program wat gekoppel word aan 'n sistematiese optimeringsproses vir die optimering van die voertuigsuspensie het dus ontstaan.

Na die aanbieding van 'n oorsig oor relevante navorsing in verband met suspensie optimering, gaan die studie voort met die ontwikkeling van 'n twee dimensionele voertuig dinamika simulasie program wat aan 'n robuuste wiskundige optimeringstegniek gekoppel word. Die optimeringsalgoritme wat vir hierdie doel gekies is, is die gradiënt gebaseerde LFOPC algoritme vir begrensde optimeringsprobleme. Met hierdie optimeringstegniek kan 'n ontwerpgebied sistematies deursoek word om die ontwerpsveranderlikes te vind wat die voertuig suspensie ten opsigte van ritgemak sal optimaliseer.

Vir bogenoemde doel is 'n twee dimensionele voertuigdinamika simulasiepakket Vehsim2d ontwikkel. Ten einde die optimering van die nie-linieêre karakteristiek van suspensiekomponente te kan uitvoer, word 'n ses-stuksgewyse kontinue linieêre benadering gevolg vir die beskrywing van die karakteristieke van die vere, dempers, deurstampstoppe, bandstyfheid en banddemping. Met hierdie benadering word twaalf ontwerpsveranderlikes gebruik vir beskrywing van die karakteristiek van elke suspensiekomponent. Die simulasieresultate is gekwalifiseer deur die simulasieresultate te vergelyk met simulasieresultate van die meer gevorderde program DADS asook eksperimenteel gemete waardes op 'n werklike militêre voertuig.

'n Uitgebreide gevallestudie waartydens die demperkarakteristieke van die drie-as militêre voertuig ge-optimeer is, word gegee. Drie verskillende padprofiele is vanaf die voertuig se mobiliteitsvereistes geselekteer as verteenwoordigende terrein waaroor die voertuigmobiliteit bewys moet word. Een van die padprofiele is 'n grondpad met lengte 2.2 km en is spesifiek ingesluit aangesien die meeste van die falings op soortgelyke terrein ondervind was. Objektiewe bepaalde ritgemak waardes by die bestuurder, massamiddelpunt, agterste passsasier en vir heibeweging van die voertuigromp is as doelfunksie tydens die optimering gespesifiseer. Vanuit die optimeringsresultate is gevind dat daar tot 'n 40% verbetering in die ritgemak verkry kan word. Hierdie resultate is weereens gekwalifiseer deur die uitvoer van simulasies met die program DADS.

Ten slotte bewys hierdie studie dat die Vehsim2d/LFOPC modellering- en optimeringstelsel 'n waardevolle gereedkapstuk vir voertuigontwerpers is.

Sleutelterme: voertuig suspensie optimering, passiewe suspensie, wiskundige programmering, gradient gebaseerde optimerings-algoritme, twee-dimensionele voertuig model

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