SOME STUDIES FOR OPTIMISATION OF ENERGY CONSUMPTION AND MUSCULAR ACTIVITY IN RICKSHAW OPERATION

by

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Submitted
In fulfillment of the requirement for the degree of
Doctor of Philosophy
to the

Indian Institute of Technology, Delhi

(JUNE 2002)

CERTIFICATE

This is to certify that the thesis entitled "Some Studies for Optimization of Energy Consumption and Muscular Activity in Rickshaw Operation" is being submitted by Ajay Somkuwar to the Indian Institute of Technology, New Delhi for the award of the degree of Doctor of Philosophy. The thesis is a bonafide record of original research work carried out by him. He has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis, which has reached the requisite standard.

The results contained in this thesis have not been submitted, in part or full, to any other University or Institute for the award of any degree or diploma.

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ACKNOWLEDGEMENT

Numerous threads in this woven cloth,
Some named, some unnamed...

As I look back to the day I joined this institute and the years that have gone by since then, I realise how much I owe to this institute and the numerous people I have come in contact with.

My research supervisors Prof. S. K. Atreya and Prof. S. K. Guha, who have nurtured it all along, sowed the seeds of my work. My association with them has been indeed a gift to me. I can never forget the numerous discussions I have had with Prof. Atreya, each of which enthused me more towards the work. His broad vision and constant interest in the progress of work continuously added life to it. My academic career owes a lot to Prof. S. K. Guha, who has been a constant source of inspiration to me. Every meeting of mine made me wonder how much there is to learn from him. His dynamism, coupled with his clarity of thought, did a great deal to mould this work. As a supervisor, he made available excellent facilities, which were indispensable for the completion of this work. Be it experiments, computations or documentation- every aspect of this work speaks by itself of his deep involvement in it. I am particularly indebted to both of them for suggesting this problem, which kept my interest alive all through the course of this work. My heartfelt thanks to both of them.

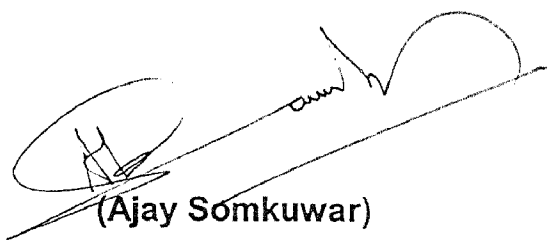
This work has had the flavour of various laboratories and computing facilities in the institute, and this could be possible only due to the co-operation and tolerance of many professors, students and other staff and his staff for

instrumentation and logistical support without which these studies would not have been possible.

I have got as much co-operation from people outside the institute as from within. Dr. Selvamurthy, Director always helped me in using their experimental facilities in Defence Institute for Physiology and Allied Sciences (DIPAS), even when their own work would have probably demanded otherwise. It is due to Dr. D. Majumdar, Mr. Paliwal and Mr. Rakesh Kumar that my work could get a flavour of real time experimental environment.

I also thank the subjects who gave their valuable time to take part in these studies. I shall always carry the fond memories of the time I have spent with Shri V. K. Midha, Mr. Surinder Sharma, Subhas and Anikji who made me feel at home away from home. Their constant support has really been indispensable. My association with them has given me much more than words can ever express. I also wish to thank to Sivani for their assistance.

This thesis has been a great test of patience for my family members. It is their patient co-operation and supports that has enabled me to complete this thesis.



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ABSTRACT

Human powered rickshaws are assembled locally with inadequate knowledge of design optimisation. Rickshaws so designed adversely affects the health of the rickshaw operators, resulting in low back pain, knee injuries, neck pain, heart and respiratory problems. In order to modify the existing design of the rickshaw for improved efficiency and performance of the operators, the force exerted on the pedal, saddle region and on the handlebars need to be known. In addition, the joint moments developed at the hip, knee and the ankle required attention. The pedalling technique of the rickshaw, which includes the tangential and normal components of the driving force and the pedal orientation over its spindle have not yet been investigated by the engineers and ergonomist. A thorough understanding of the pedalling process, energy consumption, and muscular activity could lead to improvement in efficiency of the operator and also play an important role in reducing the ailments.

The pedal forces, saddle forces and the forces exerted on the handlebars were computed using free body diagram of the rickshaw. A pedal dynamometer was developed to calculate the normal and tangential components of the driving force to the pedal. Pedal orientation was obtained by video analysis and hence the pedalling technique of the rickshaw operators was defined. Relying on a biomechanical model of the leg-rickshaw as a five -bar linkage, the kinematics of leg and joint moments at hip, knee and ankle were computed. At constant

average power of 185W, the effect of the seat tube angle and seat height on the joint moment cost function was studied. Sensitivity analysis of both the variables show that seat height is more sensitive than seat tube angle. Optimisation search was made for the combination of variable values that minimise the cost function. Seat tube angle 76° and seat height equal to 97% of trochanter leg length corresponds to the cost function global minimum. Vo_2 response was obtained for the operators under conditions similar to the normal plying of the rickshaw. Increase in oxygen consumption was observed while changing the optimal parameter. The 74.96° saddle angle and saddle height equal to 96 % of trochanter leg length was found for minimal oxygen consumption.

An EMG amplifier was developed and employed for observing the muscular activity of eight major muscles of the leg. The adverse effects of power line, cross talk, and low-level signal reception, which complicate the definition of muscle activation timing and relative intensity of the activity, have been separated via an independent component analysis technique. Integrated EMG was calculated for muscular activity analysis and median power frequency was used as an index for the rate at which the muscle fatigues. Several important conclusions have been drawn from the present study. Muscle activity patterns are not strongly related to seat tube angle and seat height; the level of muscle activity, however, is significantly affected by these variables. The saddle angle equal to 76° and seat height equal to 97% of trochanter leg length are found to be optimal for the activity of the muscles considered. Optimal activities of the muscles do not agree with the least oxygen consumption, but correlates well with the joint moments of

the leg. Quadriceps and gastrocnemius loading increases when seat height is lowered. The gluteus maximus and gastrocnemius muscles fatigue earlier while pedalling, other than the optimal value of saddle angle. The activity of tibialis anterior and hamstrings is not so serious so as to cause muscle fatigue. Examination of the kinematics pattern of lower limb indicates that major adaptation due to seat height increase occurs at the knee. The hip moment is most sensitive to the variation in seat tube angle. Ankle plantar flexion increases as the seat height increases and the seat tube angle decreases. In conclusion, it is recommended that the optimal position of the saddle should be adopted for obtaining maximum efficiency and causing minimum stress to the rickshaw operators.

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