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Design and Manufacturing of Mechanism for Rowing Simulator

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ABSTRACT

The competitive rowing is an extremely technical and physically demanding activity. The task of propelling a racing shell through given distance of water as fast as possible. It requires interaction between strength, endurance and technical skill of athletic. The basic biomechanical parameters that characterize rowing are length of stroke, duration, ratio of strokes phase, forces of stroke on handle, foot stretcher, power of stroke, trajectory of handle motion. In actual sculling it is difficult to measure these parameters. Present study deals with developing a test rig which will incorporate the actual motion of sculling at indoor rowing. This study focuses on design and manufacturing of rig to study sculling motion on dry rowing under static conditions with reference to the Indian rower's anthropometric data. Using kinematic study Equilibrium equations are developed, which verify the system under static conditions. The anthropometric data collected for Indian rowers of different age groups. It will help trainers to study and analysis the performance of the rower. With help of results obtained from the test rig the modification in sculling action for Junior and sub-junior rowers can be evaluated.

***Keywords*— sculling, simulator, mechanism, rower's anthropometric data, equilibrium equations, force measurement**

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I. INTRODUCTION

The sport of rowing is divided into two distinct categories: sculling and sweep rowing. Sculling events require each athlete to use two oars, which are pulled simultaneously and range from the single scull to the quadruple sculls. Sweep rowing events require each athlete to use one oar and range from boats containing as few as two athletes to as many as eight with coxswain[1].Each phase of the stroke has its own unique joint movements. During the catch phase, the hands are lifted, and the lower back is ridged. The catch movements include shoulder flexion and stabilization of the back and hips. During the drive, the knee and hip extend, the back remains rigid, and the arms are drawn into the chest. The knee, hip, ankle, trunk, and shoulder joints all extend during the drive. The finish involves the final movements of the arms and trunk. Back extension ceases, the hands lower into the lap, and the wrists flex, extracting the oar from the water. The recovery requires the hands to move away from the body back toward the stern of the boat, while the hip, knee, ankle, and shoulder joints flex. Understanding which movements should occur in each phase of the stroke allows coaches to design effective conditioning programs and evaluate rowing performance effectively[2].The performance of the rower can be studied by measuring forces generated at foot-stretcher, seat, handle and seat travel during a sculling stroke. Indoor rowing is best method not only to make workout regularly but also to study the performance of rower.Now a days CONCEPT 2 ergometer is used as indoor rowing machine. There is no

realistic sculling action achieved in indoor rowing machine. Sculling rig will decipher oar motion in indoor rowing machine. Though ergometer is very popular machine, it does not simulate actual sculling motion. In actual sculling oars moves in curved path and on ergometer the handle moves in straight line only.

II.LITERATURE REVIEW

There are many simulators are available like ergometer many of researchers have used ergometer (concept 2) with instruments. since the rowing in boat is not completely symmetric to the sagittal plane due to different oar motion. the hands have to cross during single stroke. therefore the use of concept 2 ergometer is not complete motion of sculling. this study focuses on development and manufacturing of test rig to simulate the sculling motion. the test rig requires mechanism to develop a same effect as actual sculling in water.required output of mechanism is that is should give resistance to oar sculling rig structure

A. Basic structure for Simulator

The parts of boat such as seat with tracks, foot-stretcherand oars are needed to be placed at the position where they should be in actual sculling boat. For this, basic structure is fabricated and parts are mounted over it. After designinga mechanism, it is placed on structure.The dimensions are taken on single scull boats which are in use at MIT boating club (fig. 2). Major dimensions are tabulated in table II.The oars will be modified with mechanism designed in it.Material used for the test rig frame- Mild steel A513. Vertical supports- 40mm x 40mm square tube thickness 2 mm, othersupports – 25mm x 25mm square tube thickness 3.048 mm. For joining arc welding process is used (fig. 3).

Fig. 1 single scull boat

B. Major dimensions of single scull boat

TABLE II-Major dimensions of boat

Sr. No.	Distance to be measured	Dimensions in mm
1	Span	1660
2	Heel Depth	150
3	Stretcher position	600
4	Stretcher angle	45°
5	Length of track	840
6	Gate height	180

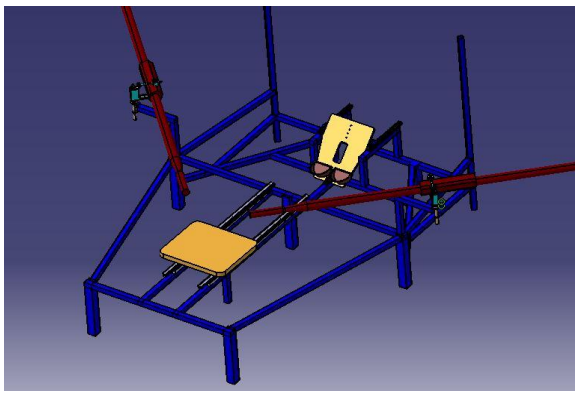

Fig.3 Structure for Rig with parts placed fixed on it

while drive stroke and while recovery it should have negligible resistance. Again from catch it follow the same cycle while workout session.

The mechanism is developed in the simulator to develop a resistance on oar. The mechanism consisting of different components attached to decipher oar motion as well as water resistance and air resistance at oars.

III.KINEMATIC EVALUATION OF FORCES

The force evaluation is done based on anthropometric data collected from active group of young rowers. The force calculations are based on fundamental mechanics applied to human body considered as system of rigid link and muscle forces under dynamic equilibrium. Free body diagram for rower on CONCEPT2 ergometer [3] is shown in fig. 1.

The acceleration of the rower (a_r) can be found out at maximum handle force condition by practical observations or by differentiating the peak velocity characteristics with respect to time. For this purpose the force time graph displayed on the machine display unit can be used. Hence static force condition at particular time interval can be used for obtaining equilibrium equation. Reference frame for forces is perpendicular to direction of motion; the system of forces is in two dimensional planes.

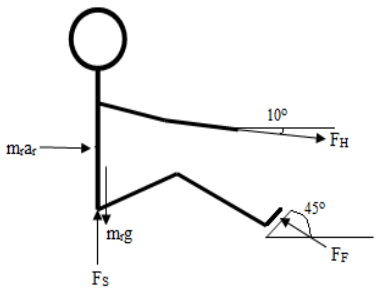

Fig. 2 FBD of Rower

Based on this FBD diagram the equations of equilibrium can be written as[4]:

$\Sigma Fx = 0$:

$Mrar + FH \cos 10 – FF \cos 45 = 0$ ---Eq. (1)

$\Sigma Fy = 0$:

$FF \cos 45 – FH \sin 10 – Mr*g + FS = 0$ --- Eq. (2)

The anthropometric data was collected from set of rowers, men and women rowers from state and National rowing team of Maharashtra state, India. The sculling motion is studied while rowers used CONCEPT2 Indoor Rowing

machine [5].Simplicity purpose linear acceleration was taken as constant till a velocity peak was reached. The velocity evaluated by measuring the number of strokes and time hence seat velocity is calculated. The weight and height have been considered for a common Indian person and the handle forces have been selected according to Indian anthropometric data. The time for one stroke to measure angular velocity and acceleration is recorded [4]. The forces calculated by equilibriumequations are listed in tableI.

IV.METHODOLOGY

In all the mechanism the fan is working as energy dissipation unit like a flywheel. The power developed by hands is transferred to fan with help of different power transmission drives like gears, belt-pulley, hydraulic cylinder, pneumatic cylinder, chain drive, etc. different attachments are being used to see complete linkage between oars and the fan.

A. *Fan-*

The fan is made up of M.S. it is radial flow fan. Base plate of fan is thick as it works as flywheel. (fig. 4)

Fig. 4 Fan

B. *Mechanism for power transmission from oar to fan.*

Major task of this study is to design a mechanism to simulate the sculling motion on the test rig. In actual sculling we can see that the rower has to apply force on foot-stretcher from catch position with foots, with helps of hands he has to work against water during drive stroke, while recovery rower have to apply negligible force on handle to take through air.The perfect rowing motion is shown in fig. 5 and direction of force exerted by oar blades.

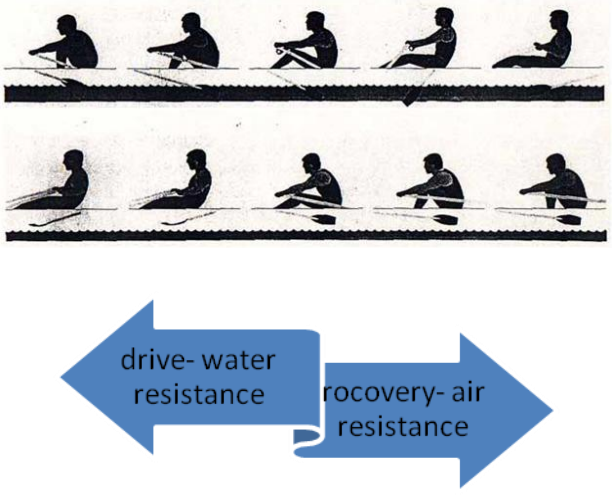

Fig. 5 forces on oar blades

There is huge difference in magnitude of the forces during drive and recovery stroke, because Oars are moving through two different fluids such as water and air. The mechanism should be such that it should provide considerable resistance during a half stroke cycle and remaining half less resistance at end of the oars. Task is to build mechanisms which transfer hand power to fan.The several mechanisms were developed during this study to simulate sculling motion. These mechanisms are explained below with their advantages along with lacunas.

C. *Mechanisms*

1) Belt drive and pulley system

Part list-V-Belt (B 72) Type - Top Width: 21/32", Height: 7/16", Inside Length: 72", Outside Length: 75", Weight: 0.74lb, Material: Rubber cushion, polyester cable cord as reinforcement and rubber impregnated woven cotton polyester fabric. 12″× 1″ B pulley (300mm), 2.5″× 1″ B pulley (60mm), Ratchet spanner 1/2″, Shafts for pulleys, Plummer block bearing (ID- 20mm),Fan.

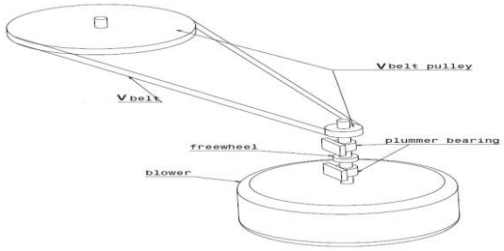

Fig.6 schematic of belt-pulley arrangement

The ratchet spanner is mounted on input shaft, handle of it works as Oar in rig. The engaged side of ratchet will give a drive strike i.e. power will be applied by rower against the fan(catch to finish of stroke). While recovery stoke means the spanner moves in oposite direction, here the rower has to take a oar to initial position on its own. While recovery there will not be resistance by fan. The same cycle will repeat again and again.The V-belt utilizes the force of friction between the inclined sides of the belt and pulley. They are preferred due to comparative shorter. Since it is flexible drive it absorbs shocks coming on it. The open belt driveconsist of V beltand two pulleys, the arrangement as shown in fig. 6. The input shaft is having a pulley1(d_1 =300mm) and output shaft is having another pulley2(d_2=60mm) (fig. 7).The centre distance is taken as 600mm.The length of belt is calculated by using formula,

$$L = 2C + \frac{\pi(d_1 + d_2)}{2} + \frac{(d_1 - d_2)^2}{4C},$$

Since d_1=300mm, d_2=60mm, C=600mm,

Length of belt is, L= 1789.56mm=1800mm

Speed ratio is of the drive is $\frac{N_1}{N_2} = \frac{d_2}{d_1} = \frac{60}{300} = \frac{1}{5}$;

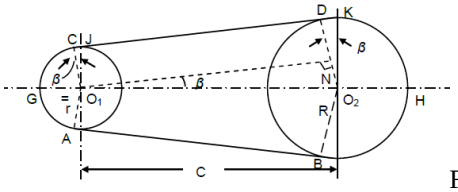

Fig. 7 belt drive

The spanner handle is given extension with UPVC pipe such that the length of spanner handle will be equal to the inboard oar length of sculling boat. The assembly was producing a sculling effect, ratchet spanner itself had a backlash. As the length of lever is increasing the arc length of backlash goes on increasing. Because the ratchet can only stop backward

motion at discrete points (i.e., at tooth boundaries), a ratchet does allow a limited amount of backward motion. This backward motion which is limited to a maximum distance equal to the spacing between the teeth is called backlash. It cannot be overlooked in case of rowing stroke because it differs from realistic sculling action.

Fig.8 Ratchet and left hand side oar showing backlash

Fig 8 shows that 'a' is length of spanner handle and 'b' is extension to spanner handle of inboard length. As arm length increases from 'a' to 'a+b', the arc length increases from 'x' to 'y'. While drive stroke at catch handle will move without any load on it. Therefore this arrangement of belt drive and pulley system is rejected.

2) Hydraulic/ Pneumatic system

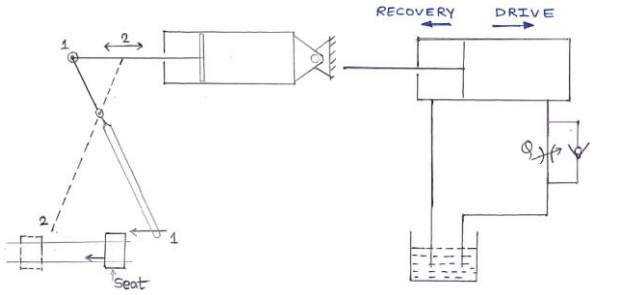

Fig. 9 Hydraulic circuit

In this system, hydraulic/ fluid pressure is used as resisting element to create feeling same as water in actual sculling. A double acting hydraulic cylinder is used and plunger (oar) is working against a fluid pressure. Hydraulic circuits consist of flow regulator, non-return valve; the load can be varied as per requirement by controlling flow of fluid through regulator. The oar's inboard length is kept same and it will work like a lever. When the oar is at catch position i.e. Position 1 and atfinish of stroke i.e. position 2 as shown in fig. 9.While drive stroke the flow of fluid is controlled through a flow control valve and at recovery oil will have open flow to oil sump. The flow of oil and forces at oar handle can be calculated by lever principle. The trial purpose developed setup for hydraulic circuit is shown in fig. 10. Force on plunger can be adjusted, that can be evaluated from following formulae;

$$Q = A \times \text{V}; P = \frac{F}{A}; \; F = P \times \text{A};$$

Fig. 10 Experimental setup for Hydraulic system

Considering average stroke rate rowersis 25 to 30 strokes per minute for training and racing respectively [10]. As frequency of strokes increases vacuum effect occurs in cylinder, due to limitations of standard accessories.This gives uncomfortable or jerkymotion of oars in sculling. Hence this system is kept aside for time.

3) Chain sprocket assembly and One way hub for fan

During this trial, fan is placed on hub, which is developed to rotate in one direction only. Now the shaft can be rotated freely in one direction and another side it will be engaged with fan. The fan is made of MDF (Medium Density fiberwood) and HIPS (High impact polystyrene) sheet. The metal plate of 200mm × 200mm having thickness 3mm is placed on back plate of fan to increase a weight and it will act as flywheel.

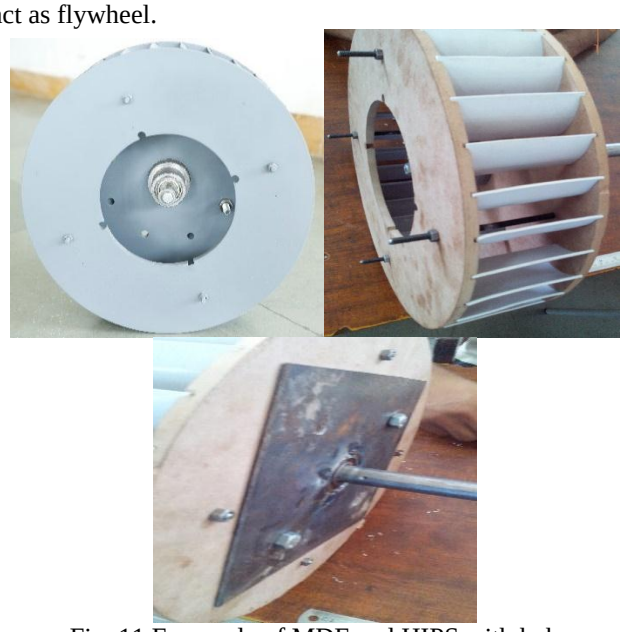

Fig. 11 Fan made of MDF and HIPS with hub

Fig. 11 shows details of fan. OD- 350mm, ID-315mm, fins are 80mm × 35mm, Number of fins-32. The grooves of depth 3mm made on MDF sheet of thickness 8mm on both sides on CNC machine. Fins are made by forming in die. Fins are inserted in Grooves between top and bottom plate and clamped with help of threaded stud.

Fig.12 hub

Fig. 12 shows the complete hub assembly used for fan. It is machined from MS solid rod. It consists of One way bearing (CSK 20p) along with two ball bearings (6003zz) for balancing of fan. One way bearing act asclutch. It makes a shaft free in one direction and transmits power in another direction. This is required from mechanism for Simulator.The oar considered for the rig is only of inboard length. The guide pin of the sculling boat is modified by using a ball joint(LHSA 12). This deciphers the oar trajectory similar to actual sculling trajectory.

Modified oar is shown in fig. 13. The shaft supporting fan with hub and sprocket at two ends respectively. The shaft is supported in between two Plummer block bearings. Bearings are fixed on the structure of the rig (fig. 14).

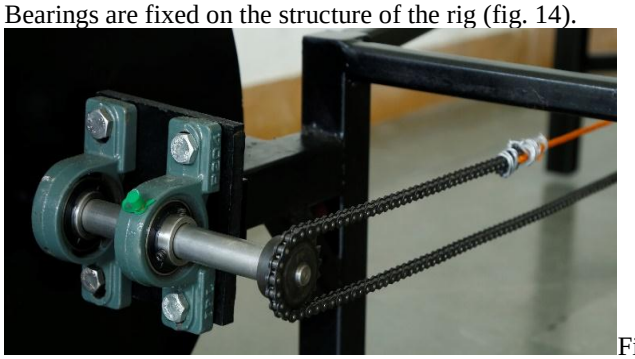

Fig. 14 Chain-Sprocket attached to fan shaft

The link between the oar, nylon rope, chain (8mm pitch), sprocket (pitch 8mm, 18 teeth), and elastic rope is shown by line diagram. The lengths of nylon rope, chain and elastic rope are 2500mm, 1500mm and 1000mm respectively. Pulleys are used for smooth motion of ropes (fig. 15).

All these parts are assembled together to decipher the oar motion realistically and complete Rowing Simulator rig is developed. The entire assembly is shown in fig. 16.

Fig.16 Rowing Simulator

V.TRIAL AND DISCUSSIONS

The teams of three rowers and a coachfrom MIT, Pune College has performed rowing on simulator with chain-sprocket assembly and one way hub for fan, daily half hours for 10 days. The motion of hands in the Simulator is completely different from Indoor rowing machines and found to be closer to actual sculling motion. The safety of the rowers has been taken in considerations while mounting on structure.With proper instrumentation forces atfoot-stretcher, seat and handle, displacement of oars can be measured easily. It will help to study performance of rower.

VI.CONCLUSION

Sculling is a physically demanding and highly technical activity. Equilibrium equations developed helps to evaluate forces at foot-stretcher, seat, and oar handle. This data helps a lot to analyse rower's performance statistically.

Among different trials conducted the chain-sprocket assembly and one way hub for fan is a perfect mechanism found for a rowing simulator.

Use of simulator makes trainer to observe rowers clearly and with help of instrumentation he able to record the data to analysis performance of rower.

Both oars having separate attachments hence simulator is useful for sculling as well as sweeping.

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