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Ergonomic Design and Analysis of Variable Resistance Biceps Machine

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ABSTRACT

Human biceps muscles are not equally strong in all positions and angular movement produces change in mechanical efficiency of the joints involved. As a result of these two factors, muscles are much stronger in some positions than in others. The resistance provided by conventional biceps machine remains constant in all positions, it will be correct in only one position and too less in all other positions throughout a full range of possible movement.

In workout gym machines built with round pulley directly in line with joints, the resistance will remain exactly the same throughout the full range of possible movements. Instead of round pulley, spiral pulley can be used so that resistance changes instantly and automatically as movement occurs and available strength changes. Physics and bio physiology, therefore, dictates the design. The strength curve of biceps muscles is the basis of design of spiral pulley.

These machines give mechanical advantage in weaker positions, as the resistance provided can be varied accordingly with the use of spiral pulley. Project aims to study, analyse using design, ANSYS software, and fabricate smoother, stronger, safer and more efficient Gym Workout Machines.

Keyword: **Strength Curve, Spiral Pulley, Cam Design, Biomechanics of Elbow**

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I. INTRODUCTION

A good working knowledge of the biomechanics of the elbow is fundamental for planning of biceps exercise. The three types of muscle contraction are Isometric, Isotonic, and Isokinetic. Isometric is defined as that type of contraction where muscle tension and muscle length remain constant. This type of exercise provides muscle strength gains but only at the joint angle held during the exercise. Isotonic contraction is defined as that where the muscle tension remains constant and muscle length varies. Isokinetic contraction is defined as varying tension and length. In each exercise there are four main functions of the associated muscles, Agonists (prime movers), Antagonists, Stabilizers and Assistors. The Agonists is generally the muscle we are exercising. The Antagonist is the opposing muscle and acts in contrast to the agonist. The Stabilizer muscles are those that hold a joint in place so that the exercise may be performed. The Assistors help the Agonist muscle doing the work. The stabilizer muscles are not necessarily moving during exercise, but provide stationary support. For example, when doing biceps curls, the biceps are the agonists, the triceps are the antagonists and various muscles including the deltoids are the stabilizer muscles. However, when doing a triceps push down, now the triceps are the agonists and the biceps are the antagonists. Again the deltoid muscles are the stabilizer muscles. The agonist/antagonist relationship changes depending on which muscle is expected to do the work. However, every muscle group has an opposing muscle group.

Biceps curl exercise machines are often used to produce effective Development of the elbow flexors. Biceps workouts can be done using machines at the gym. The exercise is using the easy bar attachment on the cable cross over. Use of biceps machine cab be started by getting a nice, comfortable grip on the bar and lifting the weights available on the machine equipment. Biceps are generally used to increase muscle strength.

II. LITERATURE REVIEW

Jaykant Gupta [1] examined the effects of these different carburization temperatures and conditions on the mechanical and wear properties of the carburized mild steels. For above purpose firstly the mild steels are carburized under the different temperature range as stated above and

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then it is tempered at 2000 C for half an hour after this the carburized and tempered mild steels are subjected for different kind of test such as abrasive wear test, hardness test, tensile test and the toughness test. The results of these experiment shows that the process of carburization greatly improves the mechanical and wear properties like hardness, tensile strength and wear resistance and these properties increases with increase in the carburization temperature but apart from this the toughness property decreases and it is further decreases with increase in carburization temperature.

SimonettaSimonettiet al. [2] studied A two-dimensional model was developed for dumbbell/barbell and cable biceps curl exercises, in quasi-static and isokinetic regimes.Analytical expressions for the ratios of the biceps force (F) and the tangent (ft) and normal (fn) components of the joint reaction to thedumbbell (Mg) and cable (c) external load were deduced as a function of the joint angle q and the other relevant parameters. For standing/preacher dumbbell curl, F and fn take their maximum values at the critical wrapping angle q*=27.4°, for any value of the preacherbench inclination a within the range 0²a²90°-q*. An increase of a yields: a) an increase in the initial value of F, and in the peak valuesof F and |fn| (up to 15Mg and 14Mg, respectively); b) a steeper decrease of F between q* and 180°-a where F=0; c) a shift of the ft(q)curve towards lower joint angles. For a³38°, the joint load becomes of compressive type (fn<0) within the whole range [0,180°-a] of thejoint motion. In cable curl, high values of the distance dP of the elbow joint from the pulley center give the same results as the standing dumbbell curl (a=0). When dPapproaches the smallest allowed values, the model predicts: a) a steep increase of F and a steep decreaseof fn and ft, just above q=0; b) high peak values of F and |fn| at q=q* (up to 15c and 13c, respectively); c) tractional values of fn smallerthan 2c and nearly constant values (~3c) of F, above q=100°.

Giovanni L. Fabian [3] introduced a new concept in the generation of strength curve profile in resistance training equipment's. Rather than of using the conventional spiral off centered cam commonly used in current resistance training equipment's, this study focuses on using a DC motor to be controlledby a micro controller to generate the strength curve as well as the resistance in resistance training equipment's. Unlike the spiral off centered cam, the method in this study will not be hampered by the limitations imposed by using a mechanical component that usually lack flexibility in thisequipment's. The concept of this study will be demonstrated in a barbell curlexercise, although the concept can also be applied to other forms of resistance training equipment's. With this study, a new and flexible alternative in the generation of strength curve profiles in resistance training equipment's can beoffered.

Tae Sik Yoon et al. [4] considered isometric and isokinetic torques of bilateral quadriceps and hamstrings were measured with lso-kinetic Rehabilitation and Testing System (Model No. Cybex 340) on 40 normal untrained subjects, 10 males and 20 females, ranging between the ages of 23 and 35 years. The mean peak isometric and isokinetic torque values of both muscle groups showed no significant differences between dominant (right) and non-dominant (left) limbs in both sexes; however there were significant differences between the male and the female. As the angular velocity increased, the peak torque significantly decreased, and the point of peak torque output occurred significantly later in the range of motion for quadriceps and hamstrings ($p<0.01$). There were no significant changes in the hamstrings to quadriceps (HjQ) ratios as the angular velocity increased. However, there were significant differences of mean H/Q ratio between male and female ($p<0.01$). Height had significantpositive correlation with peak isometric and isokinetic torques for both quadriceps and hamstrings ($p < 0.01$). Weight was found to correlate significantly with peak isometric and isokinetic torques ($p<0.01$). This mean isometric torques were significantly higher than the mean isokinetic torques for anyjoint angles in both sexes ($p<.01$).

Joseph J Knapik et al. [5] describe and examine variations inmaximal torque produced by knee extension, knee flexion, elbow extension, andelbow flexion through a range of joint motion. Subjects were young, healthy men(n = 16) and women (n = 15). Torque was measured iso-metrically and iso-kinetically using a modified cybexapparatus. Isotonic torque was calculated from aone-repetition maximum using a modified N-K® device. Joint angles were monitoredwith an electro-goniometer. Torque-joint angle curves were constructed forboth men and women for each muscle group. Isometric torque was highest, followed by isotonic and iso-kinetic torque. Torque declined with increasingiso-kinetic velocity. The angle of peak torque was found to be highly variable inindividual subjects. Variations in torque curves were explained in terms ofmechanical characteristics of the musculoskeletal system. Muscle group capabilitywas generally found to be well matched to the mechanical requirements ofthe movement.

Hong-Bo Xie et al. [6] studied ofthechaoticnature of MMG signalsby referring to recent developments in the field of nonlinear dynamics. MMG signals were measured from the biceps brachiimuscle of 5 subjects during fatigue of isometric contraction at 80% Maximal voluntary contraction (MVC)level. Deterministic chaotic character was detected in all data by using the Volterra–Wiener Korenberg model and noise titration approach. The noise limit, a power indicatorofthechaosoffatigueMMGsignals,was22.2078.73.F urthermore,westudiedthenonlinearDynamicfeaturesofMMGs ignalsbycomputingtheirr-correlation dimension D2, whichwas3.3570.36acrosssubjects. These results indicate that MMG is a high dimensional chaotic signal and support the use of the theory of nonlinear dynamics for analysis and modeling of fatigue MMG signals

III.BIO MECHANICS OF ELBOW

A good working knowledge of the biomechanics of the elbow is fundamental for planning of biceps exercise. The complex motion of the elbow joint is divided into two components that act about different axes, enabling flexion–extension. However, the literature includes papers that have sought to provide a deeper understanding of the subtleties, such as variation of the carryingangle, which might lead to

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more physiological designs of joint replacements, even if the potential benefits are as yet unproven.

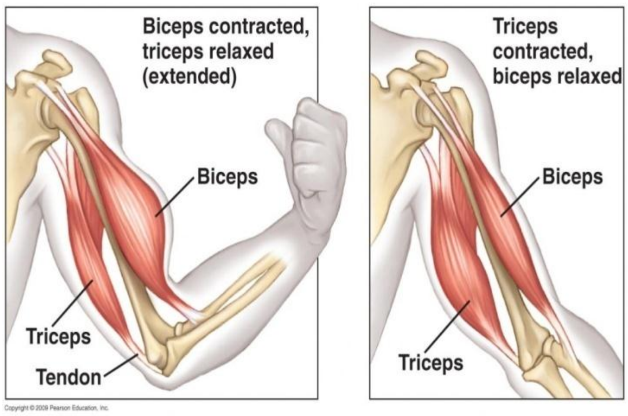

Fig.1 Biceps and Triceps muscles

IV.PULLLEY ANALYSIS

In conventional biceps machines round pulley is used for providing direction to the range of motion for the user.In order to get the percentage of forces acting, pulley of biceps machine needs to be analysed .in fig. 2 free body diagram for pulley is shown which is used of analysis the forces obtained by it.

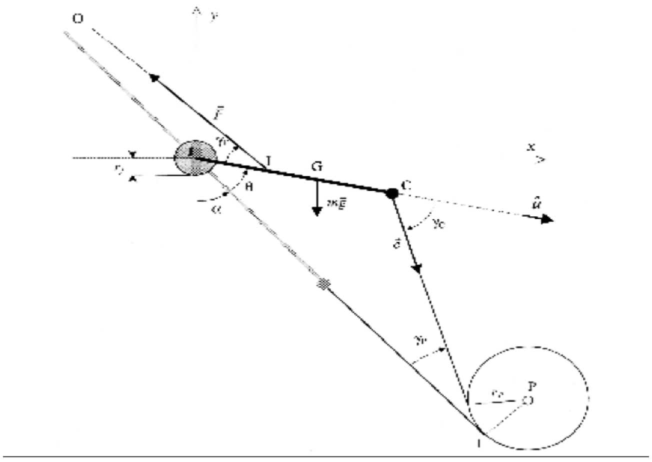

Fig.2 F.B.D. for Pulley Analysis

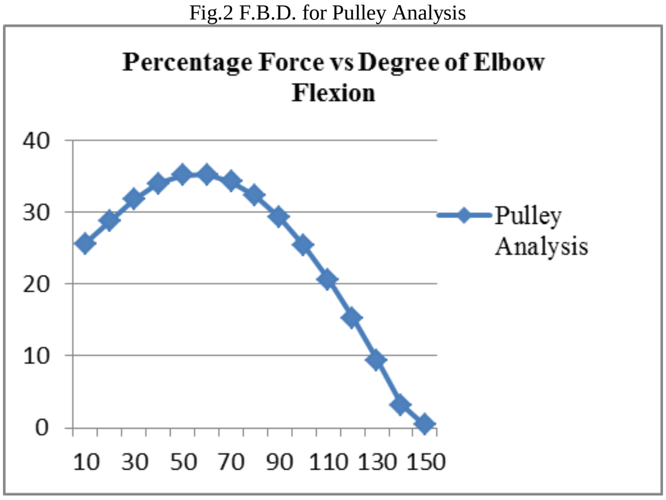

Fig.3Pulley Analysis Graph

V.DISADVANTAGES OF PULLEY

As per the biomechanics of biceps muscles is concerned muscle is week in full extended position and strong in 90 degree position. For proper workout of bicep muscle machine must offer variable resistance at different angular position and as per the strength of muscle at particular angle. In conventional bicep machine using pulley it offers constant resistant throughout the workout which is scientifically not proper. The conventional biceps curling machine offers constant resistance throughout the elbow motion during the exercise but as per anatomy and biomechanics of muscles is concerned, the curling machine must offer variable resistance. Proper workout cannot be obtained byconventional biceps machine because it offers same resistance in strong as well as weak position of muscles. Development and growth of muscles is disproportionate since during strong position muscles does not get the required resistance that is less resistance if offered whereas in weak positions the muscles are offered more resistance than the required at that position. Time required for desired result is comparatively more since the workout efficiency obtained is low.

VI.STRENGTH CURVE FOR BICEPS

The strength curve obtained in pulley analysis is totally different than that of required. As per the biomechanics is concerned the required strength curve for bicep muscles is as show in graph below.

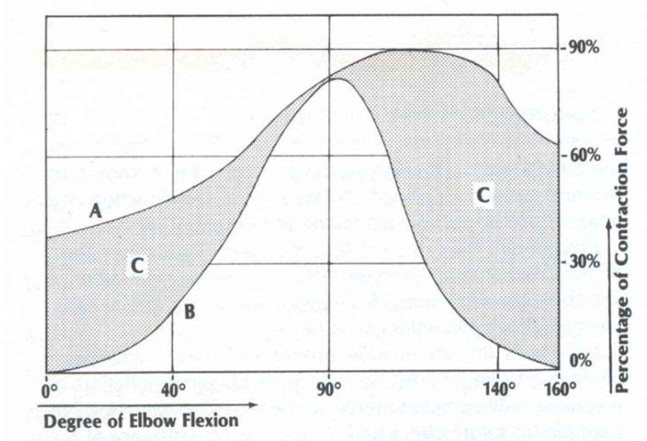

Fig.4Biceps Strength Curve

As per the graph is concerned the obtained curve of pulley and above graph is not matching so there is need to change the radius of pulley at various angle to obtain the require curve, which will obtain in case of cam.So by the above curve, calculating forces at various angles, radius at different angle to fulfill our requirement has obtained.

Calculations

T = F*R

Taking 100mm radius at base i.e. zero degree

Force = 37.33% of the actual force (from required strength curve)[fig. 4]

T = 37.33*100

T = 3733 N-mm

But machine torque will remain same throughout for particular weight. As the required force at different angle is varying radius must vary to obtained constant machine torque

So by calculating,we get following results

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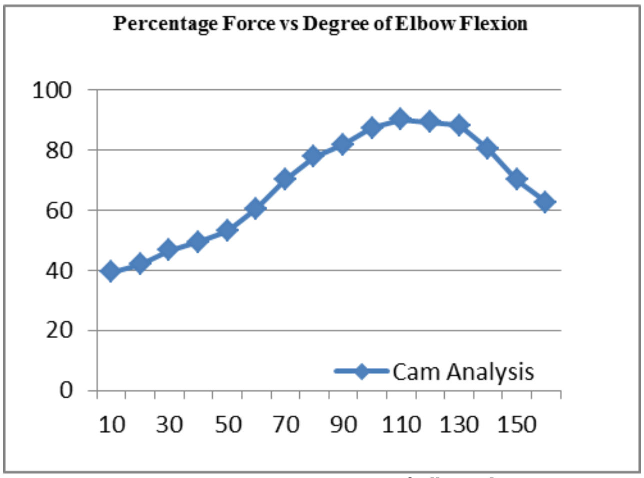

Fig.5Percentage Force Vs Degree of Elbow Flexion

VII.DIMENSIONAL MODEL

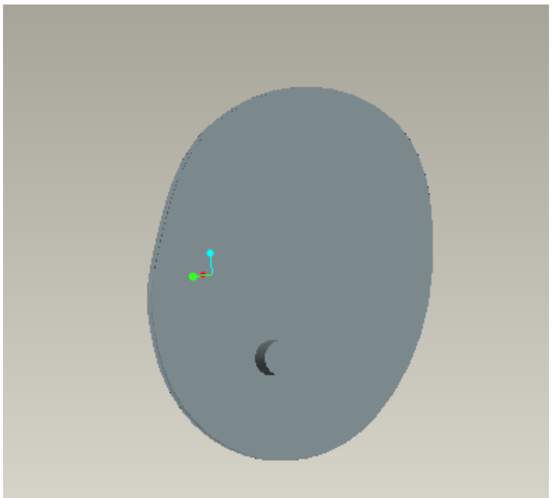

Fig.6Model of Cam

VIII.BICEPS MACHINE ANALYSIS

A. *STATIC ANALYSIS*

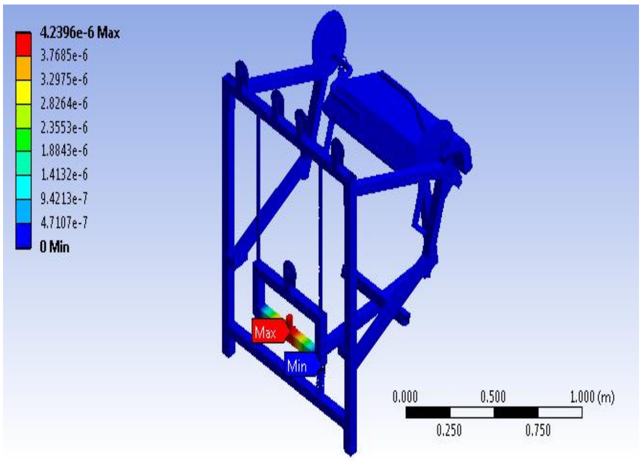

Fig.7 Total Deformation

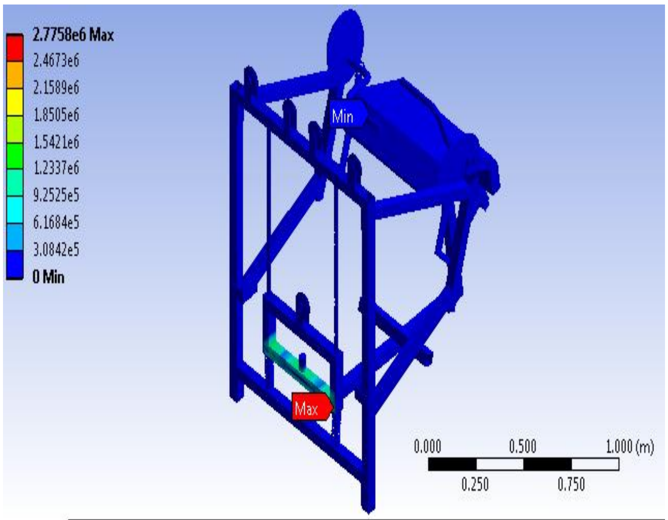

Fig.8Equivalent Stresses

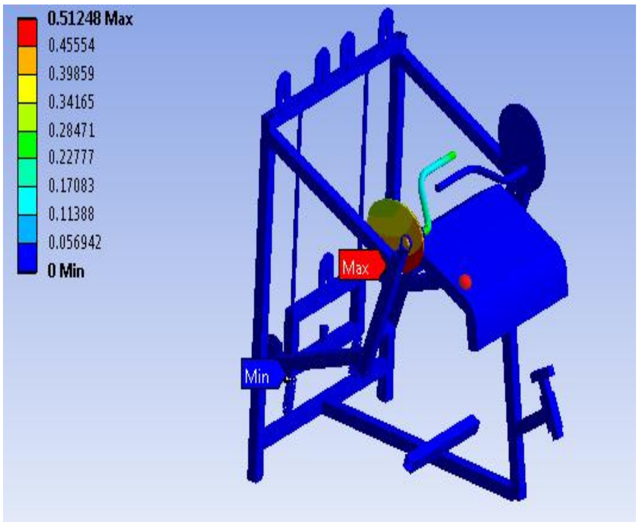

Fig.9 Modal Analysis

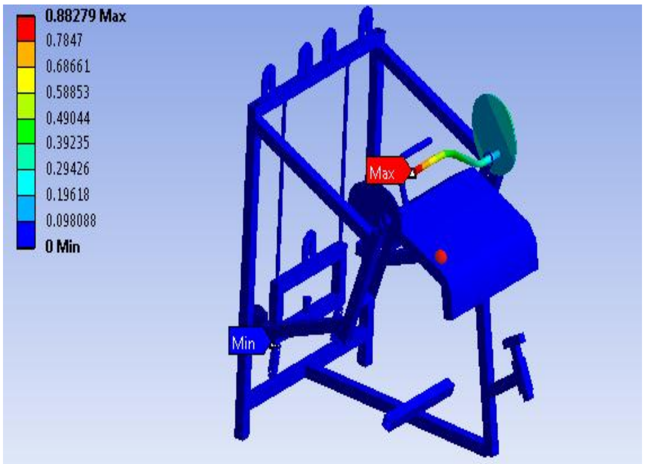

Fig.10 Modal Analysis

IX.CONCLUSION

The objective of the biceps machine was to provide variable force at different angles according to the biomechanics of elbow. This requirement was fulfilled by using cam which has different radius at different angles. Change in radius allowed the machine to exert different resistance as and when required. The application of cam in the machine helps in proper workout for the user. Since the

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cam profile is generated on the basis of strength curves of biceps, efficient workout is obtained. This reduces the workout time approximately three times as compared to conventional biceps machine. In this biceps machine relatively large diameter Nylon pulleys are used which helps in maintaining life of rope. This is because with the help of large pulley diameter the angle of contact increases which reduces the friction between the pulley and rope. This biceps machine uses free weight carriage concept instead of using dead or stack weights and nylon pulleys instead of steel pulleys. In machining equipment's the major concern for cost is these stack weights and as these stack weights are eliminated the cost of machine is reduced about 30% of the conventional machines.

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