RESEARCHERID
THOMSON REUTERS

[Vairakanna* *et al.*, 6(4): April, 2017]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

DESIGN AND MATERIAL STUDY OF RACE BIKE CRANK

PL. Vairakanna*, M. Chandran
* PG Scholar, Department of Mechanical Engineering, Dr. MGR University, Chennai, India
Professor, Department of Mechanical Engineering, Dr. MGR University, Chennai, India

DOI: 10.5281/zenodo.496091

ABSTRACT

In this study we are going to study on design and material optimization of a race bike crank. The objective is to compare the stresses and weight saving of alternate crank material with existing steel crank. Increasing strength while decreasing or maintaining weight of the products is getting to be highly important research issue in this modern world. On design study compare alternative designs of crank for effective weight reductions. The best optimized design and material will be suggested. The material will be selected with objective of increasing strength to weight ratio.

KEYWORDS: Bicycle crank, Crank Material, Crank Design Profile.

INTRODUCTION

Cranks

The two cranks, one on each side and usually mounted 180 degree apart, connect the bottom bracket axle to the pedals. Bicycle cranks can vary in length to accommodate different sized riders and different types of cycling. Crank length can be measured from the center of the pedal spindle to the center of the bottom bracket spindle or axle. The larger bicycle component manufacturers typically offers crank lengths for adult riders from 165mm to 180mm in 2.5mm increments, with 170mm cranks being the most common size. The factor affecting the selection of crank length is the rider's cycling specialty and the type of cycling event. Historically, bicycle riders have typically chosen proportionally shorter cranks for higher cadence cycling such as criterion and track racing, while riders have chosen proportionally longer cranks for lower cadence cycling such as time trial racing and mountain biking. The figure 1.1 shows the pictorial view of the bicycle crank arm

Fig: 1.1 Bicycle Crank Arm

Crank Materials

Cranks are constructed of either an Aluminum Alloy, Titanium, Carbon fiber, Chromyl Steel or some less expensive steel. Tubular steel cranks can be light and very strong, are usually found on bmx bikes, are slowly findings their way to mountain bikes (Dirt Jumping and Urban Assault). Aluminum cranks may be cast, hot forged or cold forged. Cold forging gives the metal additional strengths, and the cranks can therefore be made lighter without increasing the risk of breakage.

Crank Failures

Paddle crank failure was identified as a most critical failure point of bicycle. The analysis and optimization of a bicycle pedal crank using Finite Element Analysis (FEA) is a proposed procedure in this study. Geometry was refined by using method of body sizing till receive converged result of maximum stress. This study proposed improvements of designs with regard to minimize the weight, cost and optimization of safety. The following figure shows the pictorial view of various crank failures.

Fig: 1.2 Various Crank Failures

Failure of paddle crank means the progressive of sudden deterioration of their mechanical strength because of loadings effect. Paddle make materials shown different properties as a result many advantages as well as disadvantages. However material strength should have ability to withstand an applied stress without failure. The applied load may be tensile, compressive, or shear. Crank arm play an important role of the transfers the force exerted on the pedals to the crank set.Therefore crank arms possible to crack in a number of places. In generally crack will develop at the crotch of the chaining-mounting arms or spider arms and the crank arm. However the effects of dynamic loading are most important of the strength of bicycle crank arm, regarding the problem of fatigue. Cyclic loading often initiates brittle cracks, which grow step by step until failure occurs. However, the most often refers to various methods of calculating stresses in crank paddle arm. Tensile load is caused by an applied load that tends to elongate the crank arm material which is bicycle crank arm in the axis of the applied load, on the other hand the stress caused by elongate the material. However, such kind of materials exhibiting ductile behavior but can tolerate some defects while brittle materials structures subjected to fatigue load in metallic structure are a critical problem. It is of great importance for engineers the time a fatigue failure. Failures will occur without any early warning.

LITERATURE REVIEW

Bicycle plays an inherent role in our life. Bicycle riding is a globally popular sport and an economic transportation. The performance of crank is depends on the weight of the bicycle. Optimization of weight and structure of the bicycle crank is the best scope of optimizing the overall performance of the bicycle. When the rider ridding bicycle on rough surface, the induced vibrations will cause the fatigue of its rider and the fracture of its crank. This paper deals with the study of the structural design, modal analysis and optimization of bicycle crank by using composite material with help of FEA. Firstly structural analysis, numerical results obtained by applying dynamic loading condition. Secondly, the Modal analysis is used to identify modes of bicycle crank to calculate natural frequencies and mode shapes by using Finite Element Analysis. Finally, the analyzed crank are then optimized to reduce weight without affecting their capacity to be resistant to mechanical stresses. In this study, various literatures were reviewed about the crank material and its design.

Material Optimization of Crank

Ventzi G. Karaivanov and David A. Torick discussed the title of optimization of a bicycle crank and spider using finite element software, describes the evolution of a bicycle crank and spider design.The pedal is attached to the bicycle crank and the spider is the component that transfers the torque produced from the pedal and crank arm length to the chain sprocket. They show the deflection and stress analysis of an entry level design. The figure 2.1 shows the pictorial representation of higher end bicycle crank.

Fig: 2.1 Higher End Bicycle Crankset

Design change was to select another material to decrease the weight of the crank and spider assembly.They choosed a Glass Fiber Reinforced Plastic (GFRP). This material has a Young's Modulus of 26 GPa and a Poisson's Ratio of 0.28.This material change caused a substantial decrease in total mass of the model. The estimated weight for the crank/spider assembly decreased from 265grams (for Aluminum alloy) to 176.6 grams. However, our maximum stress of 75 MPa is much closer to the yield stress of 125 MPa for GFRP.The deflection of the end of the crank arm has also increased by a factor of three from 0.66 mm to 2.1mm. Filets throughout the model are necessary to avoid stress concentrations and injuries from sharp edges.

Weight Reduction Case Study of Crank

Sean Sullivan from Chris Huskamp, IBC Advanced Alloys (2013) discussed the case study of weight reduction of a premium road bicycle crank arm set by implementing Beralcast 310. The first part of the study concerns the direct substitution of 7050-T651Al with Beralcast 310. As mentioned previously, the crank arms are hollow forgings but the internal geometry is not known and was therefore not modeled. Graph outlines the final results of the substitution of Beralcast 310. The focus is on the relative differences between the two materials, therefore all of the results are shown as a percent difference. The figure 2.2 shows the graphical representation of weight reduction of existing crank. This study explores the Shimano Dura-Ace crank set in the following manner:

- Produce 3D CAD models of both crank arms.
- Perform FE analysis on the crank arms based on the standard 7050-T651 aluminum; this establishes a baseline strength and weight.
- Substitute the 7050-T651 Al with extruded Beralcast 310 alloy and observe the improvements in displacement and weight over the baseline figures.
- Show the potential weight savings by creating alternative versions of straight arm and compare them to the measured weight of the part.

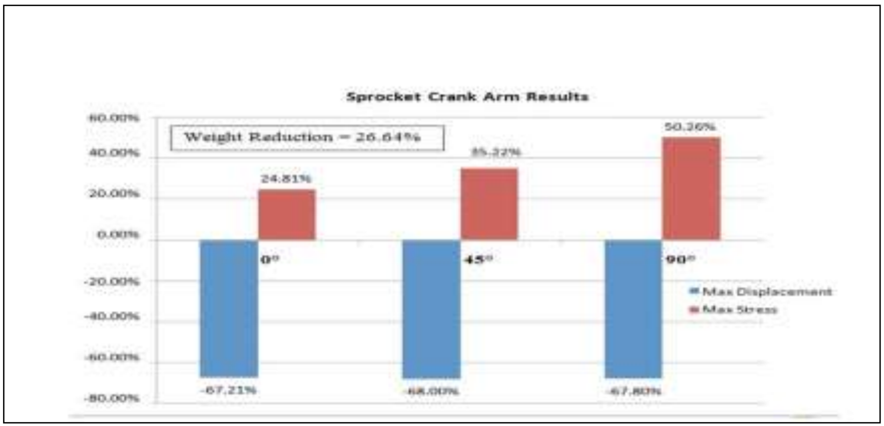

Fig: 2.2 Graphical Representation of Weight Reduction of Crank Arm

From the second part of the study, the model of the standard Dura-Ace straight crank arm was modified in five unique ways to show the potential weight savings. The figure 2.3 shows the pictorial representation of alternative design options.The weight reduction by contoured through cut is over 20%, the best out of the five unique designs. It is worth noting that each design has a small number of stress concentrations. However the focus of this study is not to create refined production quality designs but rather show the positive attributes of using Beralcast 310 for the Dura-Ace crank set. In this regard, the 310 is an improvement over the 7050-T651 Al. For all five design iterations; the overall stress levels are below yield, the weight reduction levels are 10 to 20% over the measured weight of the actual part, stiffness increases by as little as 5% and as much as 64%.

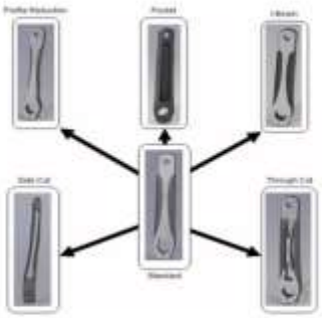

Fig 2.3 Pictorial Representation of Alternative Design

Table 1. Alternative design profiles - % of weight savings

SL.NO.	DESIGN PROFILE	% of WEIGHT REDUCTION
1	PROFILE REDUCTION	11.19
2	POCKET	13.78
3	I - BEAM	11.02
4	THROUGH CUT	9.93
5	CONTOUR CUT	20.78

Stress Analysis of Bicycle Paddle

S. Abey Gunasekara and T.M.M. Amarasekara discussed the stress analysis of bicycle paddle and optimized by finite element method, describes and proposed improvements of designs with regard to minimize the weight, cost and optimum factor of safety. Failure of paddle crank means the progressive of sudden deterioration of their mechanical strength because of loading effect. Paddle make materials shown different properties as a result many advantages as well as disadvantages. However material strength should have ability to withstand an applied stress without failure. Generally, cranks are manufactured of an aluminum alloy, titanium, carbon fiber, chromyl steel or other less expensive steel. The pedal force is changing every second in the process of turning the pedal and magnitude and direction of pedal force is different according to different riding posture. First half of the round pressure is positive and second half pressure is negative. Maximum load is coming vertically downward and magnitude is depending on the road condition, slope of the road and as well as weight of the rider. In this literature considered 95 % man's weight of the population is about 116Kg. This is the maximum load acting on pedal as well as crank in downward. Due to this load bending stress in crank and it will create twisting of the crank. The maximum bending stress gives the load acting at the end of the pedal. From this literature, we found that there is a maximum stress in sharp edges in the crank near to fixed hole so need to apply some fillets on sharp edges and more thickens near to fixed hole than the pedal fixing hole by adding material. Always it is needed to keep equivalent stress as much as low. It will benefit to durability of the component.

CONCLUSION FROM THE LITERATURE REVIEW

From the review of literature presented above, the following are the major conclusions:

i) Weight reduction of crank helps the serious cyclist and racers for fast driving. A weight reduction of 90 grams will make the design be attractive. If we use substitute material, substantial increase in deflection. Use of GFRP did have a substantial increase in deflection. Several high end crank assemblies need to be benchmarked to determine if the deflection is acceptable. If the benchmarked cranks have similar deflections the design should be acceptable to the high end consumer.

ii) Directly substituting the Beralcast 310 increases the part's stiffness by approximately 67% and decreases the weight by 26.6%. Weight reduction of 10 to 20% is possible with an increase in stiffness upto 64%.

iii) In reference to bicycle cranksets, weight and stiffness are both important characteristics. Weight reduction means the rider can obtain greater speeds and distances using less energy. Greater crank arm stiffness allows for more pedal force to be transferred to the bicycle's rear wheel rather than deform the arm.

iv) Fatigue is the progressive structural damage that occurs when materials are subjected to cyclic loading. Stress due to load on the crank was increased to maximum and decreasing to minimum. Equivalent stress should be reduced and need to keep it in an average value for durability.

DESIGN PROCESS

The basic five-step process usually used in a problem-solving works for design problems as well. Since design problems are usually defined more vaguely and have a multitude of correct answers, the process may require backtracking and iteration. Solving a design problem is a contingent process and the solution is subject to unforeseen complications and changes as it develops. Until the Wright brothers actually built and tested their early gliders, they did not know the problems and difficulties they would face controlling a powered plane. When solving a design problem, you may find at any point in the process that you need to go back to a previous step. The solution you chose may prove unworkable for any number of reasons and may require redefining the problem, collecting more information, or generating different solutions. This continuous iterative process is represented in the following Figure 3.1. The five steps for solving the design problems are:

1) Define the Problem
2) Gather Pertinent Information
3) Generate Multiple solutions

4) Analyze and select a Solution
5) Test and Implement the Solution

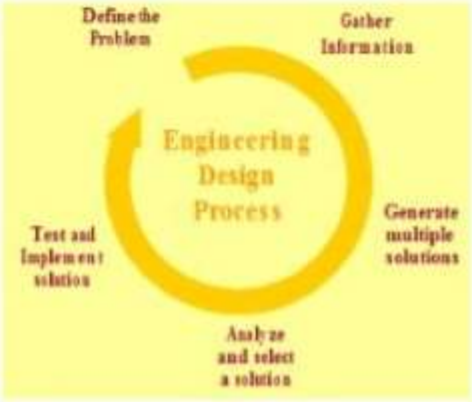

Fig: 3.1 Design Process

Problem Definition

The first step in the design process is problem definition. This definition usually contains a listing of the product or customer requirements and specially information about product functions and features among other things. Here in this paper we define the problem as bicycle crank failure. We found that in the introduction chapter.

Gather Pertinent Information

In the next step, relevant information for the design of the product and its functional specifications is obtained. A survey regarding the availability of similar products in the market should be performed at this stage. We gathered relevant information about our project from various literatures. The literature surveys were carried out in the second chapter.

Generate Multiple Solutions

Once the details of the design are clearly identified, the design team with inputs from test, manufacturing, and marketing teams generates multiple alternatives to achieve the goals and the requirements of the design. In this stage we have generate various solutions to solve the crank failure and weight reduction. We generated multiple solutions. They are following as

1. Direct Material Substitution
2. Weight Reduction by Profile Design Change
3. Method of Manufacturing

In direct material substitution, we just change the existing material by new material one without any modification in crank. In weight reduction, in addition to the material substitution a slight design modification on crank. Based on the review among different profile modification, contour through cut design modification is the best one which reduces the weight by 20%. Another solution, method of manufacturing is wire cut operation instead of forging or casting.

Analyze and Select a Solution

Considering cost, safety, and other criteria for selection, the more promising alternatives are selected for further analysis. Detail design and analysis step enables a complete study of the solutions and result in identification of the final design that best fits the product requirements. Here the bicycle crank design is to be modeled on various design software like Pro-E, Solid Works, CATIA, etc. The design can be analyzed using ANSYS software.

Test and Implement the Solution

Following this step, a prototype of the design is constructed and functional tests are performed to verify and possiability to modify the design. Analyzed design can tested with market product and identify the advantages and disadvantages when compared with existing product. Tested solution to be implemented and receive the feedback from end user for future design improvements.

RESULT AND DISCUSSION

- Various literature surveys on design of bicycle crank have been reviewed in this report and finally an optimum design of bicycle crank has been found out
- It has been found out the study presented come up with bother results as well as safe design of bicycle crank under permissible limits of various parameters and safe stresses
- Various literature surveys on material substitution for bicycle crank have been reviewed in this report
- Current work has to be concluded up with the fact that slight and careful variation in design parameters gives a significant design which can be made feasible by a number of analysis using CAE tools and software

CONCLUSION

- Weight reduction of crank helps the serious cyclist and racers for fast driving. A weight reduction by Aluminum alloy of 90 grams will make the design be attractive
- Directly substituting the Beralcast 310 increases the part's stiffness by approximately 67% and decreases the weight by 26.6%.
- In reference to bicycle cranksets, weight and stiffness are both important characteristics. Weight reduction means the rider can obtain greater speeds and distances using less energy. Greater crank arm stiffness allows for more pedal force to be transferred to the bicycle's rear wheel rather than deform the arm.
- Fatigue is the progressive structural damage that occurs when materials are subjected to cyclic loading. Stress due to load on the crank was increased to maximum and decreasing to minimum. Equivalent stress should be reduced and need to keep it in an average value for durability.

REFERENCES

[1] Vevtzi G. Karaivanov, David A. Torick, " Optimization of a Bicycle Crank and Spider Using Finite Element Software"
[2] Sean Sullivan (2013), "Weight Reduction Case Study of a Premium Road Bicycle Crank Arm Set by Implementing Beralcast 310"
[3] S. Abeygunasekara, T.M.M. Amarasekara, "Stress Analysis of Bicycle Paddle and Optimized by Finite Element Method"
[4] G.M Sayeed Ahmed, Sirajuddin Elyas Khany, Syed Hamaz Shareef, "Design, Fabrication and Analysis of a Connecting Rod with Aluminum Alloys and Carbon Fiber"
[5] Aparna Deshpande, Amol B. Gaiwad, "Design and Optimization of Bicycle Frame for the Cyclist's Comfort"
[6] V. Sarath Teja, D.V.S.S.S.V. Prasad, K.S.B.S.V.S. Sastry, "Numerical Study on materials and Design Optimization of a Bicycle Frame"
[7] Dr. B.K. Roy, "Design Analysis and Optimization of Various Parameters of Connecting Rod using CAE Softwares"