DESIGN AND ANALYSIS OF A FOUR WHEELER CRANK SHAFT BY DIFFERENT ALUMINUM ALLOYS

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Abstract— A crankshaft is used to convert reciprocating motion of the piston into rotary motion or vice versa. The crankshaft consists of the shaft parts which revolve in the main bearings, the crankpins to the big ends of the connecting rod are connected, the crank arms or webs which connects the crankpins and the shaft parts. The crankshafts are subjected to shock and fatigue loads. Thus material of the crankshaft should be tough and fatigue resistant. The common materials used for crankshaft are Carbon Steel or Nickel-Chrome-Moly alloy steel or Nickel-Chrome or special cast iron. The aim of the project is to design and manufacturing a crankshaft for a four cylinder IC engine by using theoretical calculations in design area for Aluminum alloys6061 and commercial grade. A 2D drawing is drafted for crankshaft from the calculations and a 3D model is created in the 3D modeling software CREO

Introduction to crankshaft:

The crankshaft, sometimes casually abbreviated to crank, is the part of an engine which translates reciprocating linear piston motion into rotation. To convert the reciprocating motion into rotation, the crankshaft has "crank throws" or "crankpins", additional bearing surfaces whose axis is offset from that of the crank, to which the "big ends" of the connecting rods from each cylinder attach. It typically connects to a flywheel, to reduce the pulsation characteristic of the four-stroke cycle, and sometimes a torsional or vibrational damper at the opposite end, to reduce the torsion vibrations often caused along the length of the crankshaft by the cylinders farthest from the output end acting on the torsional elasticity of the metal.

1) CRANKSHAFT MANUFACTURING PROCESSES: Many high performance crankshafts are formed by the forging process, in which a billet of suitable size is heated to the appropriate forging temperature, typically in the range of 1950 - 2250°F, and then successively pounded or pressed into the desired shape by squeezing the billet between pairs of dies under very high pressure. These die sets have the concave negative form of the desired external shape. Complex shapes and / or extreme deformations often require more than one set of dies to accomplish the shaping.

Originally, two-plane V8 cranks were forged in a single plane, then the number two and four main journals were reheated and twisted 90° to move crankpins number two and three into a perpendicular plane. Later developments in forging technology allowed the forging of a 2-plane "non-twist" crank directly (Figure 1).

Figure:1

Two-Plane V8 Crankshaft Raw Forging

Crankshafts at the upper end of the motorsport spectrum are manufactured from billet. Billet crankshafts are fully machined

from a round bar ("billet") of the selected material (Figure 2). This method of manufacture provides extreme flexibility of design and allows rapid alterations to a design in search of optimal

performance characteristics. In addition to the fully-machined surfaces, the billet process makes it much easier to locate the counterweights and journal webs exactly where the designer wants them to be. This process involves demanding machining

operations, especially with regard to counterweight shaping and undercutting, rifle-drilling main and rod journals, and drilling lubrication passages. The availability of multi-axis, high-speed,

high precision CNC machining equipment has made the carved-from-billet method quite cost-effective, and, together with exacting 3D-CAD and FEA design methodologies, has enabled the

manufacture of extremely precise crankshafts which often require very little in the way of subsequent massaging for balance purposes.

Figure:2

Billet Crankshaft Machining (Courtesy of Bryant Racing)

There is an old argument that a forged crank is superior to a billet crank because of the allegedly uninterrupted grain flow that can be obtained in the forging process. That might be true of some components, but with respect to crankshafts, the argument fails because of the large dislocations in the material that are necessary to move the crankpin and counterweight material from the center of the forging blank to the outer extremes of the part. The resulting grain structure in the typical V8 crank forging exhibits similar fractured grain properties to that of a machined billet. More than one crankshaft manufacturer has told me that there is no way that a forging from the commonly used steel alloy SAE-4340 (AMS-6414) would survive in one of today's Cup engines.

Some years ago, there was an effort at Cosworth to build a Formula One crankshaft by welding together various sections, which comprised the journals, webs and counterweights. The purported intent was to be better able to create exactly the shape and section of the various components, thereby reducing MMOI while achieving the same or better stiffness. While no one was willing to divulge details about the effort, it is rumored to have been run once or twice then abandoned due to the high cost and complexity compared to the measurable benefits.

In certain cases, there are benefits to the use of a built-up crankshaft. Because of the ‘master-rod’ mechanism necessary for the implementation of the radial piston engines that powered most aircraft until well into the second half of the 20th century, a bolted-together crankshaft configuration was used almost exclusively. Figure 5 illustrates a typical two-row composite radial crankshaft and master-rod layout. The loose counterweights will be addressed later in this article.

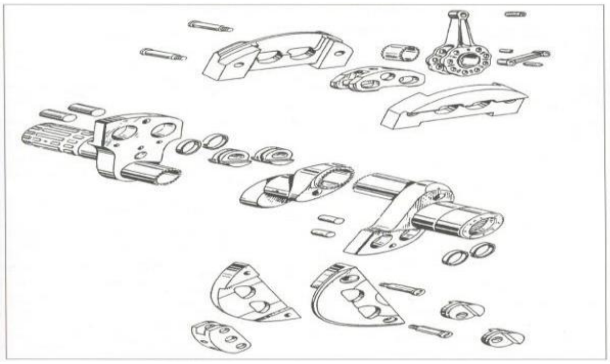


Figure:3
Built-up Radial Engine Crank

2) CRANKSHAFT MATERIALS:

The steel alloys typically used in high strength crankshafts have been selected for what each designer perceives as the most desirable combination of properties. Figure 4 shows the nominal chemistries of the crankshaft alloys discussed here.

Medium-carbon steel alloys are composed of predominantly the element iron, and contain a small percentage of carbon (0.25% to 0.45%, described as ‘25 to 45 points’ of carbon), along with combinations of several alloying elements, the mix of which has been carefully designed in order to produce specific qualities in the target alloy, including hardenability, nitridability, surface and core hardness, ultimate tensile strength, yield strength, endurance limit (fatigue strength), ductility, impact resistance, corrosion resistance, and temper-embrittlement resistance. The alloying elements typically used in these carbon steels are manganese, chromium, molybdenum, nickel, silicon, cobalt, vanadium, and sometimes aluminium and titanium. Each of those elements adds specific properties in a given material. The carbon content is the main determinant of the ultimate strength and hardness to which such an alloy can be heat treated.

Chemistry of Crankshaft Alloys
Nominal Percentages of Alloying Elements

Material	AMS	C	Mn	Cr	Ni	Mo	Si	V
4340	6414	0.40	0.75	0.82	1.85	0.25		
EN-30B		0.30	0.55	1.20	4.15	0.30	0.22	
4330-M	6427	0.30	0.85	0.90	1.80	0.45	0.30	0.07
32-CrMoV-13	6481	0.34	0.55	3.00	<0.30	0.90	0.25	0.28
300-M	6419	0.43	0.75	0.82	1.85	0.40	1.70	0.07

Key: C = Carbon, Mn = Manganese, Cr = Chromium, Ni = Nickel, Mo = Molybdenum, Si = Silicon, V = Vanadium, AMS = Aircraft Material Spec Number

Figure: 4

In addition to alloying elements, high strength steels are carefully refined so as to remove as many of the undesirable impurities as possible (sulfur, phosphorous, calcium, etc.) and to more tightly constrain the tolerances, which define the allowable variations in the percentage of alloying elements. The highest quality steels are usually specified and ordered by reference to their AMS number (Aircraft Material Specification). These specs tightly constrain the chemistry, and the required purity can often only be achieved by melting in a vacuum, then re-melting in a vacuum to further refine the metal. Typical vacuum-processing methods are VIM and VAR.

There are other ultra-high-strength steels that are not carbon steels. These steels, known as "maraging" steels, are refined so as to remove as much of the carbon as possible, and develop their extreme strength and fatigue properties as a by-product of the crystalline structures resulting from the large amounts of nickel (15% and up) and cobalt (6% and up) they contain. These steels can achieve extreme levels of strength and maintain excellent levels of impact resistance. As far as I could determine, maraging alloys are not currently (2008) used for racing crankshafts but they have been used in certain extreme application conrods.

The material which is currently viewed as the ultra-extreme crankshaft alloy is a steel available from the French manufacturer Aubert & Duval, known as 32-CrMoV-13 or 32CDV13. It is a deep-nitriding alloy containing 300 points of chrome, developed in the mid-nineties specifically for aerospace bearing applications. It is available in three grades. GKH is the commercial purity and chemistry tolerance. GKH-W is the grade having higher purity (VAR) and tighter chemistry tolerance. GKH-YW is the extremely pure grade (VIM - VAR) and is said to cost twice as much per pound as the -W grade.

According to data supplied by Aubert & Duval, fatigue-tests of the -W and -YW grades, using samples of each grade heat treated to similar values of ultimate tensile strength, show consistently that the -YW grade achieves a dramatic improvement (over 22%) in fatigue strength compared to the -W grade, and the endurance limit is claimed to be just a bit short of the yield stress, which is truly amazing. I have been told that, because of the extreme stress levels on Formula One crankshafts, most of them use the -YW grade, while the lower stress levels of a Cup crank allow the successful use of the -W grade.

One well-known manufacturer (Chambon) has developed a process which allows the production of a deep case nitride layer in this alloy (almost 1.0 mm deep, as compared to the more typical 0.10 to 0.15 mm deep layer). They say this deeper case provides a far less sharp hardness gradient from the >60 HRc surface to the 40-45 HRc core, which improves the fatigue and impact properties of the steel. It says that its deep-case process requires several days in the nitriding ovens, but the depth allows finish-grinding after nitriding, using a very sophisticated process to remove the distortions which occurred during the nitriding soak.

No discussion of high-end crankshaft materials would be complete without mention of the ultra-high-strength alloy known as 300-M (AMS 6419). This alloy is a modification to the basic 4340 chemistry, in which a few more points of carbon are added (higher achievable hardness and strength), along with 170 points of silicon and 7 points of vanadium. The vanadium acts as a grain refiner, and the silicon enables the material to be tempered to very high strength (285 ksi) and fatigue properties, while retaining extremely good impact resistance and toughness.

This material (300-M) is expensive and sometimes hard to get, since it is preferred for heavy aircraft landing gear components. It has been used by a few manufacturers for extreme duty crankshafts and conrods as well as high-shock aircraft components. However, several of the manufacturers I spoke with told me that they consider their favorite materials to be much better than 300-M for crankshaft applications.

3 DESIGN OF CRANKSHAFT: SPECIFICATIONS:-

Lml freedom Bore diameter or cylinder bore = D=69.6mm Stroke

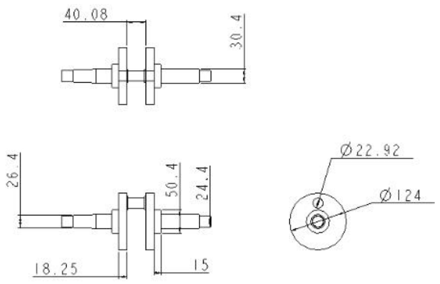
= 82mm Explosion pressure gas pressure =P =10.936 N/mm2 Maximum torque = 200 N-m @1750-3000 rpm Design of crank shaft when the crank is at the dead centre We know that piston gas load Now the various parts of the crank shaft are design as discussed below: 1. Design of crank pin: let We have Takin 41585.951= Let us now the included bending stress in the crank pin We know that bending moment at the crank pin M = Section modules of the crank pin Z = Bending stress induced The induced bending stress is within in the permissible limits of 560 Mpa, therefore design of crank pin is safe. 2. Design of bearings Let Let us take thickness of the crank web t = 0.6 length of bearing WKT bending moment at centre of bearing M = =41585.951(0.75) =6133927.773 Bending moment (M) WKT 6133927.773= 3.

Design of crank web Let w = width of the crank web in mm WKT bending moment on the crank web M = =41585.951(0.75)=2703086.815 Section modulus Z = Bending stress Total stress on the crank web = Total stress should not exceed permissible limit of 560 Mpa 560 = W = 17.390=20mm Design of shaft under the flywheel: Let First of all let us find the horizontal and vertical reactions at the bearings 1 and 2 Allowing

for certain clearance the distance b = W+ 300+ 442mm and a= 0.75 WKT the horizontal reactions at bearings 1 and 2 due to the piston gas load () are Assuming The vertical reactions at bearings a1 and 2 ue to the weight of flywheel are W = weight of flywheel = 1.18kg=11.57N There is no belt tension the horizontal reactions due to the belt tension are neglected WKT horizontal bending moment at the flywheel location due to piston gas load = 3066964 There is no belt pull. There will be no horizontal bending moment due to the belt pull, i.e Total horizontal bending moment WKT vertical bending moment due to the flywheel weight

Resultant bending moment = = 3066964.266 We know that bending moment 3066964.266.

2D DRAWING



INTRODUCTION TO CAD

Computer-aided design (CAD), also known as computer-aided design and drafting (CADD), is the use of computer technology for the process of design and design-documentation. Computer Aided Drafting describes the process of drafting with a computer. CADD software, or environments, provide the user with input-tools for the purpose of streamlining design processes; drafting, documentation, and manufacturing processes. CADD output is often in the form of electronic files for print or machining operations. The development of CADD-based software is in direct correlation with the processes it seeks to economize; industry-based software (construction, manufacturing, etc.) typically uses vector-based (linear) environments whereas graphic-based software utilizes raster-based (pixelated) environments.

CADD environments often involve more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application-specific conventions.

CAD may be used to design curves and figures in two-dimensional

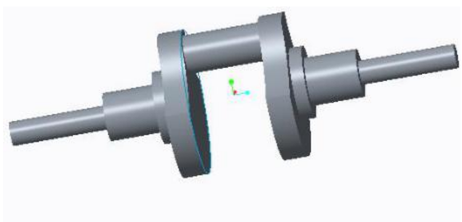
(2D) space; or curves, surfaces, and solids in three-dimensional

(3D) objects.

INTRODUCTION TO CREO

PTC CREO, formerly known as Pro/ENGINEER, is 3D modeling software used in mechanical engineering, design, manufacturing, and in CAD drafting service firms. It was one of the first 3D CAD modeling applications that used a rule-based parametric system. Using parameters, dimensions and features to capture the behavior of the product, it can optimize the development product as well as the design itself. The name was changed in 2010 from Pro/ENGINEER Wildfire to CREO. It was announced by the company who developed it, Parametric Technology Company (PTC), during the launch of its suite of design products that includes applications such as assembly modeling, 2D orthographic views for technical drawing, finite element analysis and more.

The time saved by using PTC CREO isn't the only advantage. It has many ways of saving costs. For instance, the cost of creating a new product can be lowered because the development process is shortened due to the automation of the generation of associative manufacturing and service deliverables. PTC also offers comprehensive training on how to use the software. This can save businesses by eliminating the need to hire new employees.



ADVANTAGES OF CREO PARAMETRIC SOFTWARE

1. Optimized for model-based enterprises
2. Increased engineer productivity
3. Better enabled concept design
4. Increased engineering capabilities
5. Increased manufacturing capabilities
6. Better simulation
7. Design capabilities for additive manufacturing

CREO parametric modules:

- Sketcher
- Part modeling
- Assembly
- Drafting

INTRODUCTION TO FEA

Finite element analysis is a method of solving, usually approximately, certain problems in engineering and science. It is used mainly for problems for which no exact solution, expressible in some mathematical form, is available. As such, it is a numerical rather than an analytical method. Methods of this type are needed because analytical methods cannot cope with the real, complicated problems that are met with in engineering. For example, engineering strength of materials or the mathematical theory of elasticity can be used to calculate analytically the stresses and strains in a bent beam, but neither will be very successful in finding out what is happening in part of a car suspension system during cornering.

INTRODUCTION TO ANSYS

ANSYS Autodyn is computer simulation tool for simulating the response of materials to short duration severe loadings from impact, high pressure or explosions.

1. ANSYS Mechanical

ANSYS Mechanical is a finite element analysis tool for structural analysis, including linear, nonlinear and dynamic studies. This computer simulation product provides finite elements to model behavior, and supports material models and equation solvers for a wide range of mechanical design problems. ANSYS Mechanical also includes thermal analysis and coupled-physics capabilities involving acoustics, piezoelectric, thermal–structural and thermo-electric analysis.

2. Fluid Dynamics

ANSYS Fluent, CFD, CFX, FENSAP-ICE and related software are Computational Fluid Dynamics software tools used by engineers for design and analysis. These tools can simulate fluid flows in a virtual environment — for example, the fluid dynamics of ship hulls; gas turbine engines (including the compressors, combustion chamber, turbines and afterburners); aircraft aerodynamics; pumps, fans, HVAC systems, mixing vessels, hydro cyclones, vacuum cleaners, etc.

Definitions of Results obtained

Displacement - A vector quantity which refers to the distance which an object has moved in a given direction. It is measured as the length of a straight line between the initial and final positions of a body.

Von Mises Stress - The Von Mises criteria is a formula for combining these 3 stresses into an equivalent stress, which is then compared to the tensile stress of the material.

RESULTS

As per the analysis images

	Displacement (mm)	Von Mises Stress (N/mm^2)	Von-mises strain
Aluminum alloy 7475	0.004071	13.3622	0.191e-03
Aluminum alloy 6061	0.004154	13.6322	0.199e-03

Thermal analysis results table

	Nodal temperature(k)	Thermal gradient	Thermal flux
Aluminum alloy 7475	558	52.7603	7.20082
Aluminum alloy 6061	558	49.4276	8.5987

Manufacturing component

Casting Process

Consider the casting process at 645 B.C, the first traces of the Sand Molding was found. Now consider the state-of-the-art Electromagnetic casting process. Truly, the Casting process has traversed a long path and impacted human civilization for nearly five millennia. With technological advances, metal casting is playing a greater role in our everyday lives and is more essential than it has ever been.

Selecting the Right Metal Casting Process

• For any Metal Casting Process, selection of right alloy, size, shape, thickness, tolerance, texture, and weight, is very vital.

• Special requirements such as, magnetism, corrosion, stress distribution also influence the choice of the Metal Casting Process.

• Views of the Tooling Designer; Foundry / Machine House needs, customer's exact product requirements, and secondary operations like painting, must be taken care of before selecting the appropriate Metal Casting Process.

• Tool cost.

• Economics of machining versus process costs.

• Adequate protection / packaging, shipping constraints, regulations of the final components, weights and shelf life of protective coatings also play their part in the Metal Casting process.

Comparative Advantages, Disadvantages and Applications for

Various Casting Methods:

Advantages	Disadvantages	Recommended Application
Least Expensive in small quantities (less than 100) Ferrous and non - ferrous metals may be cast Possible to cast very large parts. • Least expensive tooling	Dimensional accuracy inferior to other processes, requires larger tolerances Castings usually exceed calculated weight Surface finish of ferrous castings usually exceeds 125 RMS	Use when strength/weight ratio permits Tolerances, surface finish and low machining cost does not warrant a more expensive process
Permanent and Semi-permanent Mold Casting		
Less expensive than Investment or Die Castings Dimensional Tolerances closer than Sand Castings Castings are dense and pressure tight	Only non-ferrous metals may be cast by this process Less competitive with Sand Cast process when three or more sand cores are required Higher tooling cost than Sand Cast	Use when process recommended for parts subjected to hydrostatic pressure Ideal for parts having low profile, no cores and quantities in excess of 300

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CONCLUSION

In our project we have designed a crankshaft for a multi cylinder engine using theoretical calculations and modeled the crankshaft in parametric software creo. Pressure produced in the engine is also calculated.

Structural and modal analysis is done on the crankshaft to validate our design. Analysis is done for two materials aluminum alloy 6061 and Aluminum alloy7475.

By observing the stress values for both the materials, the analyzed stress values are less than their respective yield stress values. So our design is safe.

By comparing the stress results for both materials, it is less for Aluminum alloy7475 than aluminum alloy 6061.

So for our designed crankshaft, using Aluminum alloy 7475 is best.

REFERENCES

1. Design of machine member’s vol.1&2 by R.S Kurmi, S.Chand publications.

2. C.M.Balamurugan.,R.Krishnaraj.,Dr.M.Sakthive.l, .Kanthave.l,DeepanMarudachalam M.G., R.Palani., 2011“Computer Aided Modeling and Optimization of Crankshaft, ’’International Journal of Scientific & Engineering Research Volume 2, Issue 8 ISSN 2229-5518

3. Yu Ding and Xiaobo Li.,2011, “ Crankshaft Strength Analysis of a Diesel Engine Using Finite Element Method,” Asia -Pacific Power and Energy Engineering Conference

4. JianMeng., Yongqi Liu., Ruixiang Liu.,2011,“Finite Element Analysis of 4-Cylinder Diesel Crankshaft, ” I.J. Image, Graphics and Signal Processing, 5, 22-29

5. Yu Gongzh.i, Yu Hongliang.,DuanShulin., 2011, “Crankshaft Dynamic Strength Analysis for Marine Diesel Engine,” Third International Conference on Measuring Technology and MechatronicsAutomation