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Design and Structural Analysis of a V12 Engine by using different materials.

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Abstract

A **V12 engine** often just called a **V12** is an internal combustion engine with 12 cylinders. The engine has six cylinders on each side called banks. The two banks form a "V" shaped angle. In most engines, the two banks are at a 60° angle to each other. All twelve pistons turn a common crankshaft. It can be powered by different types of fuels, including gasoline, diesel and natural gas. A V12 engine does not need balance shafts. A V12 angled at 45°, 60°, 120°, or 180° from each other has even firing and is smoother than a straight-6. This provides a smooth running engine for a luxury car. In a racing car, the engine can be made much lighter. This makes the engine more responsive and smoother. In a large heavy-duty engine, a V12 can run slower and prolonging engine life.

The main objective of the project is how to develop the prototype of V 12 engine assembly using CAD tool SOLIDWORKS. These Engine assembly consists major components they are Piston, Connecting Rod Assembly, Crank Shaft, Cylinder head, Cam Shaft, Valves, crank case, oil tank and spark plug with required dimensions. The components which are developed in SOLIDWORKS are also analyzed in it using simulation tool. The thermal analysis of piston, crank shaft, cam shaft and valve is performed for 800k thermal loading and the results of temperature distribution of the components are shown. Finally the thermal analysis results of the components are compared and the best suited material is selected.

INTRODUCTION

We almost take our Internal Combustion Engines for granted don't we? All we do is buy our vehicles, hop in and drive around. There is, however, a history of development to know about. The compact, well-toned, powerful and surprisingly quiet engine that seems to be purr under your vehicle's hood just wasn't the tame beast it seems to be now. It was loud, it used to roar and it used to be rather bulky. In fact, one of the very first engines that had been conceived wasn't even like the engine we know so well of today. An internal combustion engine is defined as an engine in which the chemical energy of the fuel is released inside the engine and used directly for mechanical work, as opposed to an external combustion engine in which a separate combustor is used to burn the fuel. The internal combustion engine was conceived and developed in the late 1800s. It has had a significant impact on society, and is considered one of the most significant inventions of the last century. The internal combustion engine has been the foundation for the successful development of many commercial technologies. For example, consider how this type of engine has transformed the transportation industry, allowing the invention and improvement of automobiles, trucks, airplanes and trains.

Internal combustion engines can deliver power in the range from 0.01 kW to 20x103 kW, depending on their displacement. The complete in the market place with electric motors, gas turbines and steam engines. The major applications are in the vehicle (automobile and truck), railroad, marine, aircraft, home use and stationary areas. The vast majority of internal combustion engines are produced for vehicular applications, requiring a power output on the order of 102 kW. Next to that internal combustion engines have become the dominant prime mover technology in several areas. For example, in 1900 most automobiles were steam or electrically powered, but by 1900 most automobiles were powered by gasoline engines. As of year 2000, in the United States alone there are about 200 million motor vehicles powered by internal combustion engines. In 1900, steam engines were used to power ships and railroad locomotives; today two- and four-stoke diesel engines are used. Prior to 1950, aircraft relied almost exclusively on the pistons engines. Today gas turbines are the power plant used in large planes, and piston engines continue to dominate the market in small planes. The adoption and continued use of the internal combustion engine in different application areas has resulted from its relatively low cost, favorable power to weight ratio, high efficiency, and relatively simple and robust operating characteristics.

The components of a reciprocating internal combustion engine, block, piston, valves, crankshaft and connecting rod have remained basically unchanged since the late 1800s. The main differences between a modern day engine and one built 100 years ago are the thermal efficiency and the emission level. For many years, internal combustion engine research was aimed at improving thermal efficiency and reducing noise and vibration. As a consequence, the thermal efficiency has increased from about 10% to values as high as 50%. Since 1970, with recognition of the importance of air quality, there has also been a great deal of work devoted to reducing emissions from engines. Currently, emission control requirements are one of the major factors in the design and operation of internal combustion engines.

V 12(12 cylinder engine)

A V12 engine is a V engine with 12 cylinders mounted on the crankcase in two banks of six cylinders, usually but not always at a 60° angle to each other, with all 12 pistons driving a common crankshaft. Since each cylinder bank is essentially a straight-6 which is by itself in both primary and secondary balance, a V12 is automatically in primary and secondary balance no matter which V angle is used, and therefore it needs no balance shafts. A four-stroke 12 cylinder engine has an even firing order if cylinders fire every 60° of crankshaft rotation, so a V12 with cylinder banks at a multiples of 60° (60°, 120° or 180°) will have even firing intervals without using split crankpins. By using split crankpins or just ignoring minor vibrations, any V angle is possible. The 180° configuration is usually referred to as a flat-12or even a boxer although it is in reality a 180° V since the pistons can and normally do use shared crankpins.

Applications of V12 engine:

V12 engines deliver power pulses more often than engines with six or eight cylinders, and the power pulses have triple overlap (at any time three cylinders are on different stages of the same power stroke) which eliminates gaps between power pulses and allows for greater refinement and smoothness in a luxury car engine, at the expense of much greater cost. In a racing car engine, the rotating parts of a V12 can be made much lighter than a V8 with a cross plane crankshaft because there is no need to use heavy counterweights on the crankshaft and less need for the inertial mass in a flywheel to smooth out the power delivery. Exhaust system tuning is also much more difficult on a cross plane V8 than a V12, so racing cars with V8 engines often use a complicated bundle of snakes exhaust system, or a flat-plane crankshaft which causes severe engine vibration and noise. This is not important in a race car if all-out performance is the only goal. Since cost and fuel economy are usually important even in luxury and racing cars, the V12 has been largely phased out in favor of engines with fewer cylinders.

In a large displacement, high-power engine, a 60° V12 fits into a longer and narrower space than a V8 and most other V configurations, which is a problem in modern cars, but less so in heavy trucks, and seldom a

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problem in large stationary engines. The V12 is very common in locomotive and battle tank engines, where enormous power is required but the width of the engine is constrained by tight railway clearances or street widths, while the length of the vehicle is more flexible. It is often used in marine engines where great power is required, and the hull width is limited, but a longer vessel allows faster hull speed. In twin-propeller boats, two V12 engines can be narrow enough to sit side-by-side, while three V12 engines are sometimes used in high-speed three-propeller configurations. Large, fast cruise ships can have six or more V12 engines. In historic piston-engine fighter and bomber aircraft, the long, narrow V12 configuration used in high performance aircraft made them more streamlined than other engines, particularly the short, wide radial engine. During World War II the power of fighter engines was stepped up to extreme levels using multi-speed superchargers and ultra-high octane gasoline, so the extreme smoothness of the V12 prevented the powerful engines from tearing apart the light airframes of fighters (often made out of balsa wood and/or canvas rather than aluminum). After World War II, the more compact, more powerful and vibration-free turboprop and turbojet engines replaced the V12 in aircraft applications.

Main components of the engine:

Piston:

Piston is one of the main parts in the engine. Its purpose is to transfer force from Expanding gas in the cylinder to the crankshaft via a connecting rod.

Since the piston is the main reciprocating part of an engine, its movement creates an imbalance. This imbalance generally manifests itself as a vibration, which causes the engine to be perceivably harsh. The friction between the walls of the cylinder and the piston rings eventually results in wear, reducing the effective life of the mechanism. The sound generated by a reciprocating engine can be intolerable and as a result, many reciprocating engines rely on heavy noise suppression equipment to diminish droning and loudness. To transmit the energy of the piston to the crank, the piston is connected to a connecting rod which is in turn connected to the crank. Because the linear movement of the piston must be converted to a rotational movement of the crank, mechanical loss is experienced as a consequence. Overall, this leads to a decrease in the overall efficiency of the combustion process. The motion of the crank shaft is not smooth, since energy supplied by the piston is not continuous and it is impulsive in nature. To address this, manufacturers fit heavy flywheels which supply constant inertia to the crank. Balance shafts are also fitted to some engines, and diminish the instability generated by the pistons movement. To supply the fuel and remove the exhaust fumes from the cylinder there is a need for valves and camshafts. During opening and closing of the valves, mechanical noise and vibrations may be encountered.

Figure: piston

Pistons are commonly made of a cast aluminum alloy for excellent and lightweight thermal conductivity. Thermal conductivity is the ability of a material to conduct and transfer heat. Aluminum expands when heated, and proper clearance must be provided to maintain free piston movement in the cylinder bore. Insufficient clearance can cause the piston to seize in the cylinder. Excessive clearance can cause a loss of compression and an increase in piston noise.

Piston features include the piston head, piston pin bore, piston pin, skirt, ring grooves, ring lands, and piston rings. The piston head is the top surface (closest to the cylinder head) of the piston which is subjected to tremendous forces and heat during normal engine operation.

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A piston pin bore is a through hole in the side of the piston perpendicular to piston travel that receives the piston pin. A piston pin is a hollow shaft that connects the small end of the connecting rod to the piston. The skirt of a piston is the portion of the piston closest to the crankshaft that helps align the piston as it moves in the cylinder bore. Some skirts have profiles cut into them to reduce piston mass and to provide clearance for the rotating crankshaft counterweights.

Piston Rings:

A ring groove is a recessed area located around the perimeter of the piston that is used to retain a piston ring. Ring lands are the two parallel surfaces of the ring groove which function as the sealing surface for the piston ring. A piston ring is an expandable split ring used to provide a seal between the piston an the cylinder wall.

Piston rings are commonly made from cast iron. Cast iron retains the integrity of its original shape under heat, load, and other dynamic forces. Piston rings seal the combustion chamber, conduct heat from the piston to the cylinder wall, and return oil to the crankcase. Piston ring size and configuration vary depending on engine design and cylinder material.

Piston rings commonly used on small engines include the compression ring, wiper ring, and oil ring. A compression ring is the piston ring located in the ring groove closest to the piston head. The compression ring seals the combustion chamber from any leakage during the combustion process. When the air-fuel mixture is ignited, pressure from combustion gases is applied to the piston head, forcing the piston toward the crankshaft. The pressurized gases travel through the gap between the cylinder wall and the piston and into the piston ring groove. Combustion gas pressure forces the piston ring against the cylinder wall to form a seal. Pressure applied to the piston ring is approximately proportional to the combustion gas pressure.

Figure: piston rings

Connecting Rod:

The connecting rod is a major link inside of a combustion engine. It connects the Piston to the crankshaft and is responsible for transferring power from the piston to the crankshaft and sending it to the transmission. There are different types of materials and production methods used in the creation of connecting rods. The most common types of connecting rods are steel and aluminum. The most common type of manufacturing processes are casting, forging and powdered metallurgy.

The connecting rod is the most common cause of catastrophic engine failure. It isan enormous amount of load pressure and is often the recipient of special care to ensure that it does not fail prematurely. The sharp edges are sanded smooth in an attempt to reduce stress risers on the rod. The connecting rod is also shot-preened, or hardened, to increase its strength against cracking. In most high-performance applications, the connecting rod is balanced to prevent unwanted harmonics from creating excessive wear. The most common connecting rod found in production vehicle engines is a cast rod. This type of rod is created by pouring molten steel into a mold and then machining the finished product. This type of rod is reliable for lower horsepower-producing engines and is the least expensive to manufacture. The cast rod has been used in nearly every type of engine, from gasoline to diesel, with great success.

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Figure : connecting rod

Crankshaft:

The crankshaft is the part of an engine which translates reciprocating linear piston motion into rotation. To convert the reciprocating motion into rotation, the crank shaft has crankpins, additional bearing surfaces whose axis is offset from that of the crank, to which the "big ends" of the connecting rod 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 torsion elasticity of the metal.

Figure: crankshaft

The engine's crankshaft is made of very heavy cast iron in most cases and solid steel in very high-performance engines. The crankshaft's snout must be made very strong to withstand the stress of placing the crankshaft pulley and the stress created from driving all of the components off of that single pulley.

Camshaft :

Camshaft is frequently called "brain" of the engine. This is so because its job is to open and closed at just the right time during engine rotation, so that the maximum power and efficient cleanout of exhaust to be obtained. The camshaft drives the distributor to electrically synchronize spark ignition. Camshafts do their work through eccentric "lobes" that actuate the components of the valve train. The camshaft itself is forged from one piece of steel, on which the lobes are ground. On single-camshaft engines there are twice as many lobes as there are cylinders, plus a lobe for fuel pump actuation and a drive gear for the distributor. Driving the camshaft is the crankshaft, usually through a set of gears or a chain or belt. The camshaft always rotates at half of crank rpm, taking two full rotations of the crankshaft to complete one rotation of the cam, to complete a four-stroke cycle. The camshaft operates the lifters (also called tappets or cam followers) that in turn operate the rest of the valve train. On "overhead valve" engines the lifters move pushrods that move rocker arms that move valve stems. Lifters can be of several types. The most common are hydraulic, mechanical and roller lifters. Hydraulic lifters fill with oil that acts as a shock absorber to eliminate clearance in the valve train. They are quiet and don't require periodic adjustment. Mechanical lifters are solid metal and require scheduled adjustment for proper valve clearance. These are used in high-rpm applications. Roller lifters use a roller device at one end and can be hydraulic or mechanical. They are used in applications where a very fast rate of valve lift is required. The camshaft material should combine a strong shaft with hard cam lobes. The most widely used material at present is chilled or forged cast iron.

Figure: cam shaft

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SOLID WORKS

Solid Works is mechanical design automation software that takes advantage of the familiar Microsoft Windows graphical user interface.

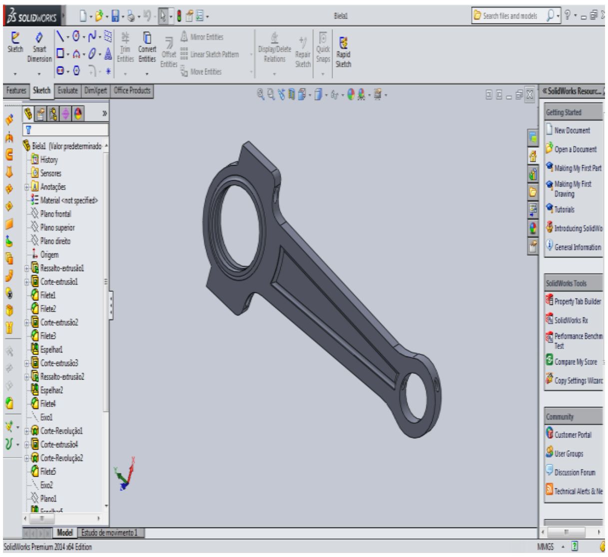
It is an easy-to-learn tool which makes it possible for mechanical designers to quickly sketch ideas, experiment with features and dimensions, and produce models and detailed drawings.

A Solid Works model consists of parts, assemblies, and drawings.

- Typically, we begin with a sketch, create a base feature, and then add more features to the model. (One can also begin with an imported surface or solid geometry).
- We are free to refine our design by adding, changing, or reordering features.
- Associatively between parts, assemblies, and drawings assures that changes made to one view are automatically made to all other views.
- We can generate drawings or assemblies at any time in the design process.
- The Solid works software lets us customize functionality to suit our needs.

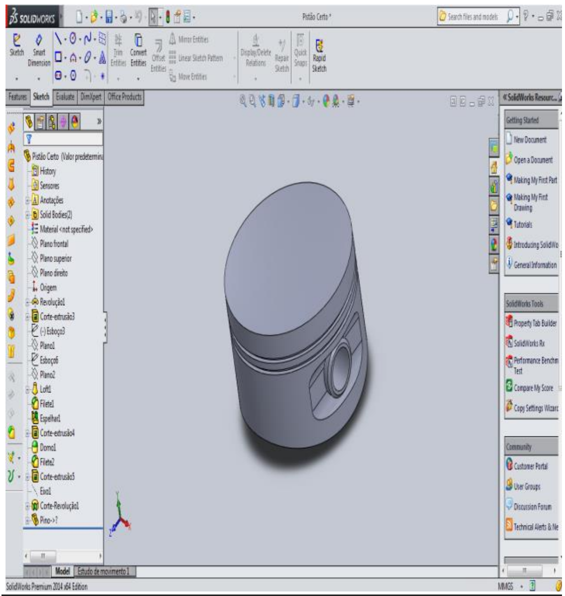
Model of V12 engine:

Connecting rod:



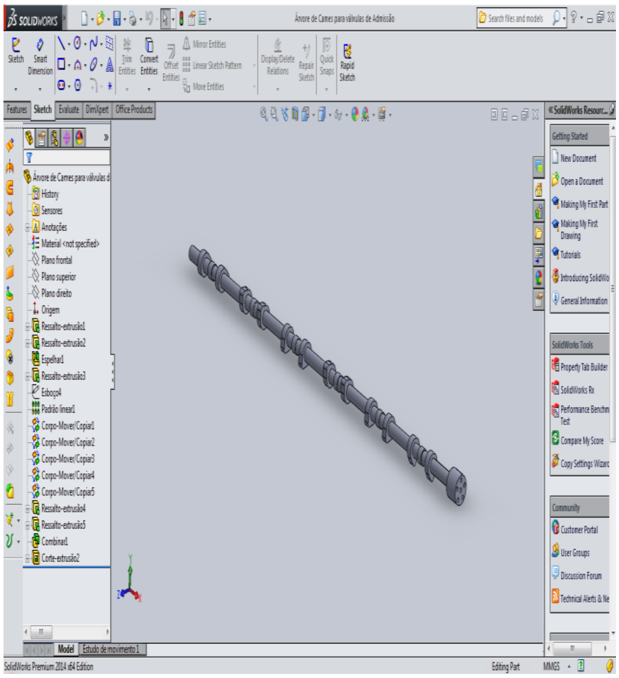
By using extrude, extrude cut, fillet, chamfer, planes can generate the connecting rod.

Piston:



By using revolve, loft, fillet, evaluate, extrude, cut extrude can generate the piston head.

Cam shaft:



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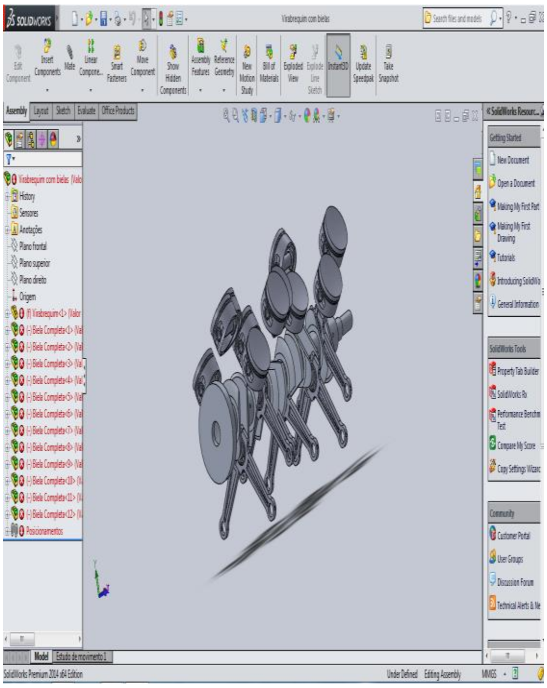
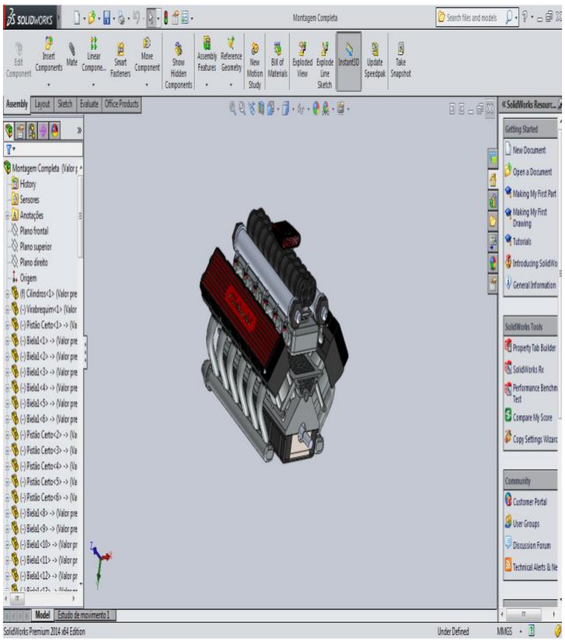
Assembly of cam shaft, piston:



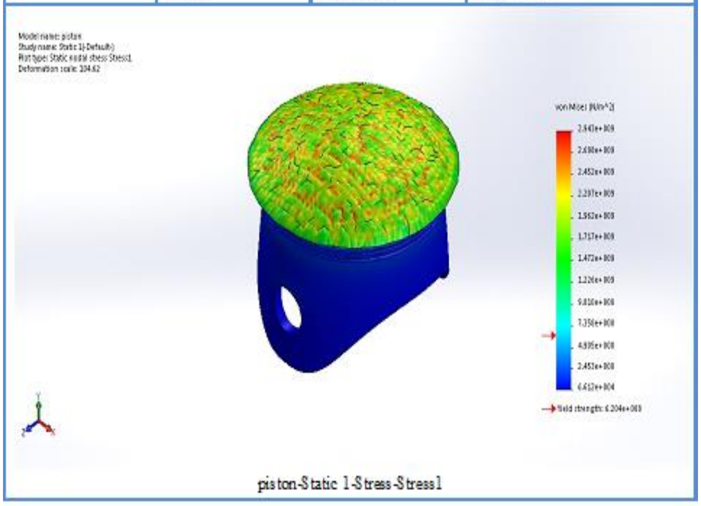
Complete assembly of V12 engine:



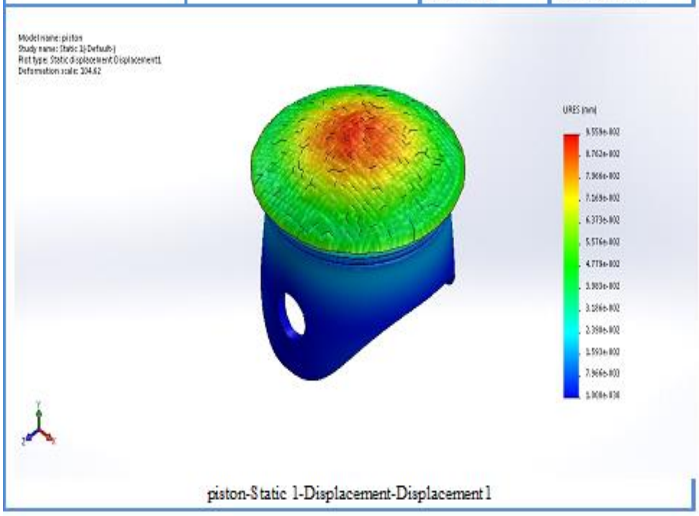
Simulation and analysis of piston:

Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	66117.9 N/m^2 Node: 3990	2.94296e+009 N/m^2 Node: 58778



Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 658	0.095589 mm Node: 59133



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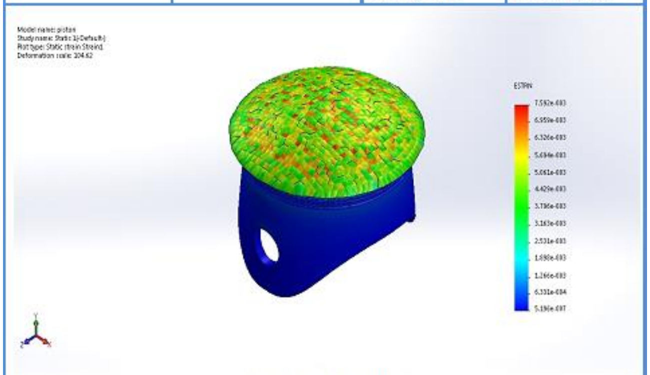
Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	5.19552e-007 Element: 50023	0.00759158 Element: 32225



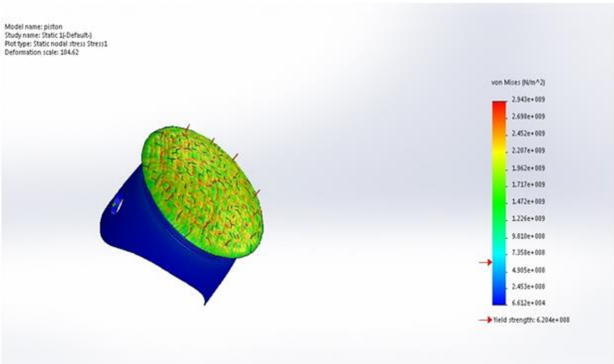


Image-1

Analysis on cast alloy steel:

Loads and Fixtures

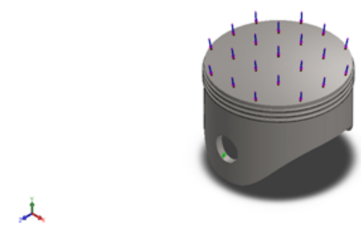
Fixture name	Fixture Image	Fixture Details
Fixed-1		Entities: 2 face(s) Type: Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	0.00207579	9.8964	-0.0052861	9.8964
Reaction Moment(N.m)	0	0	0	0

Load name	Load Image	Load Details
Force-1		Entities: 1 face(s) Type: Apply normal force Value: 10 N
Temperature-1		Entities: 1 face(s) Temperature: 1200 Kelvin

Model Information



Model name: piston
Current Configuration: Default

Solid Bodies

<L_MdInf_SldBd_Nm/>	Treated As	Volumetric Properties	Document Path/Date Modified
Cut-Extrude2 	Solid Body	Mass:1.25053 kg Volume:0.000171306 m^3 Density:7300 kg/m^3 Weight:12.2552 N	\\10.0.0.4\e\Mechanical\javeed\ic engines\ic engines\piston.SLDPRT Jan 20 15:44:44 2014
<L_MdInf_ShlBd_Nm/>	<L_MdIn_ShlBd_Fr/>	<L_MdInf_ShlBd_VolProp/>	<L_MdIn_ShlBd_DtMd/>
<L_MdInf_CpBd_Nm/>	<L_MdInf_CompBd_Props/>		
<L_MdInf_BmBd_Nm/>	<L_MdIn_BmBd_Fr/>	<L_MdInf_BmBd_VolProp/>	<L_MdIn_BmBd_DtMd/>

Mesh Information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	2.77847 mm
Tolerance	0.138923 mm
Mesh Quality	High

Mesh Information - Details

Total Nodes	88439
Total Elements	57345
Maximum Aspect Ratio	7.9751
% of elements with Aspect Ratio < 3	99.7
% of elements with Aspect Ratio > 10	0
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:10
Computer name:	MEC-131-PC

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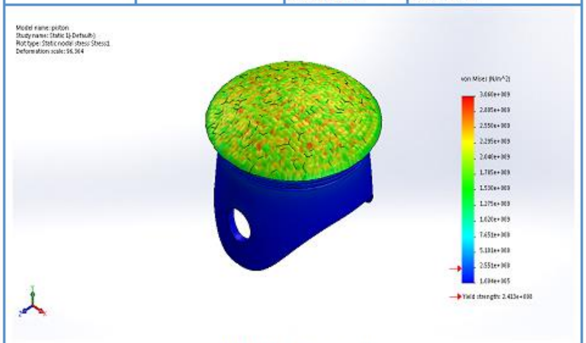
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	100427 N/m^2 Node: 71569	3.06027e+009 N/m^2 Node: 65773



piston-Static 1-Stress-Stress1

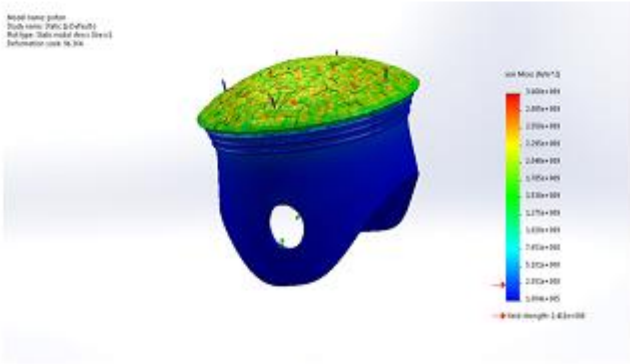
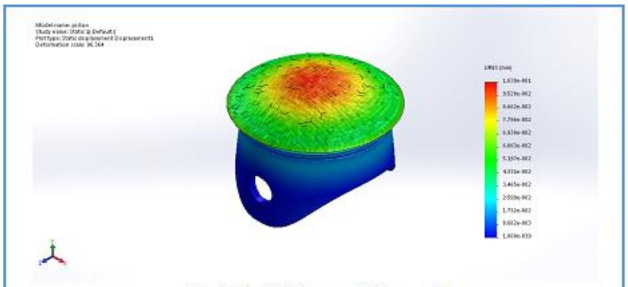


Image-1



piston-Static 1-Displacement-Displacement1

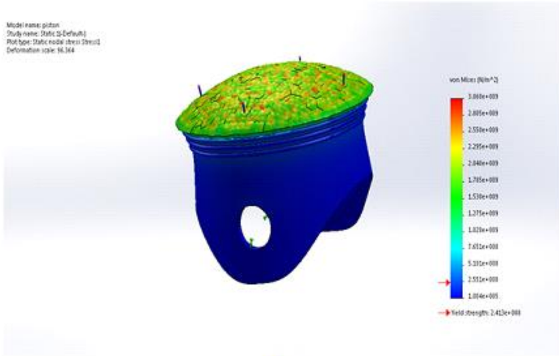
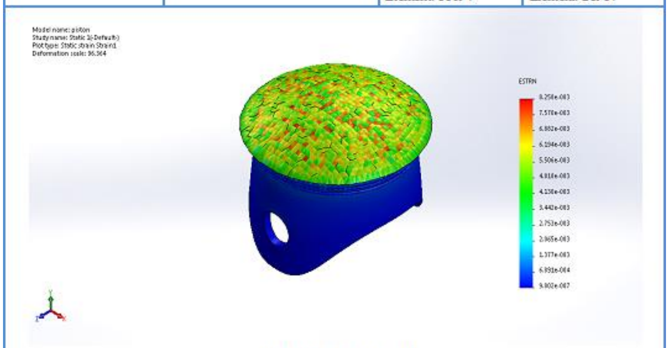


Image-2

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	9.80236e-007 Element: 31694	0.00825832 Element: 21984



piston-Static 1-Strain-Strain1

Static analysis on connecting rod (alloy steel)

Material properties

Model Reference	Properties	Components
	Name: Alloy Steel Model type: Linear Elastic Isotropic Default failure criterion: Max von Mises Stress Yield strength: 620.422 N/mm^2 Tensile strength: 723.826 N/mm^2 Elastic modulus: 210000 N/mm^2 Poisson's ratio: 0.28 Mass density: 7700 g/cm^3 Shear modulus: 79000 N/mm^2 Thermal expansion coefficient: 1.3e-005 /Kelvin	SolidBody 1(Combinar1)(Biela1)
Curve Data:N/A		

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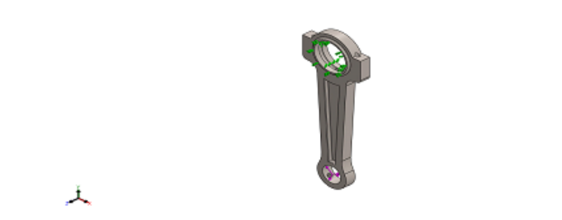
Model information



Model name: Biela1
Current Configuration: Valor predeterminado

Solid Bodies			
<L_MdInf_SldBd_Nm>	Treated As	Volumetric Properties	Document Path/Date Modified
Combinar1 	Solid Body	Mass:0.398873 kg Volume:5.18016e-005 m^3 Density:7700 kg/m^3 Weight:3.90895 N	D:\project analysis files\V 12 engine document\V12 part files\Peças\Biela1.SLDPRT Jan 21 14:52:01 2015

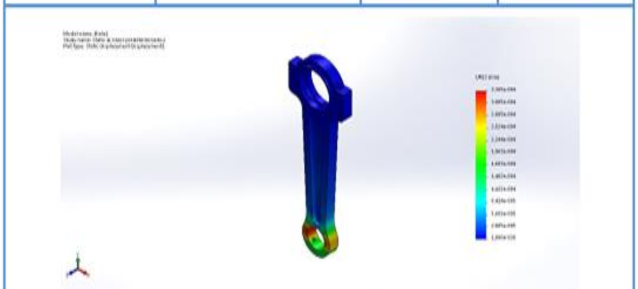
Deformation

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 1	0.00033654 mm Node: 86416

Biela1-Static 1-Displacement-Displacement1

Strain

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	2.85781e-011 Element: 19592	3.96062e-005 Element: 11602



Biela1-Static 1-Strain-Strain1

Static analysis on connecting rod (1023 steel)

Material properties

Model Reference	Properties	Components
	Name: 1023 Carbon Steel Sheet (SS) Model type: Linear Elastic Isotropic Default failure criterion: Max von Mises Stress Yield strength: 282.685 N/mm^2 Tensile strength: 425 N/mm^2 Elastic modulus: 205000 N/mm^2 Poisson's ratio: 0.29 Mass density: 7858 g/cm^3 Shear modulus: 80000 N/mm^2 Thermal expansion coefficient: 1.2e-005 /Kelvin	SolidBody 1(Combinar1)(Biela1)

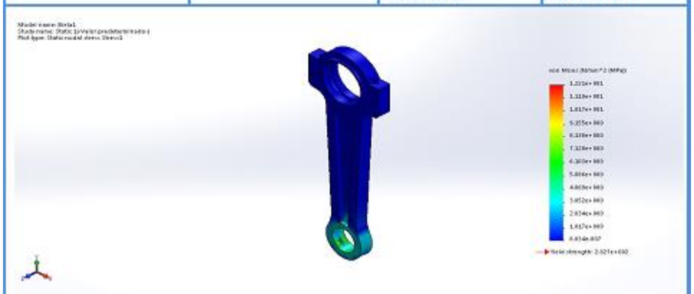
Model information

Model name: Biela1
Current Configuration: Valor predeterminado

	Treated As	Volumetric Properties	Document Path/Date Modified
Combinar1	Solid Body	Mass:0.407057 kg Volume:5.18016e-005 m^3 Density: 7858 kg/m^3 Weight:3.98916 N	D:\project analysis files\V 12 engine document\V12 part files\Peças\Biela1.SLDPRT Jan 21 14:52:01 2015

Stress

Name	Type	Min	Max
Stress1	VON: von Mises Stress	8.83419e-007 N/mm^2 (MPa) Node: 83287	12.2065 N/mm^2 (MPa) Node: 97871



Biela1-Static 1-Stress-Stress1

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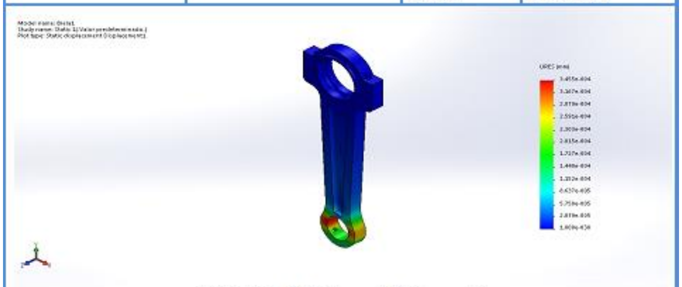
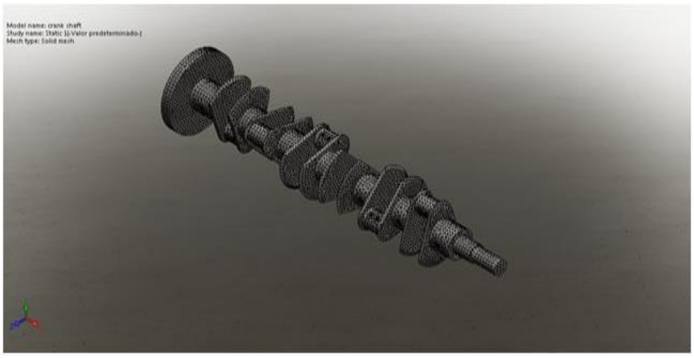
Deformation

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 1	0.000345495 mm Node: 86416



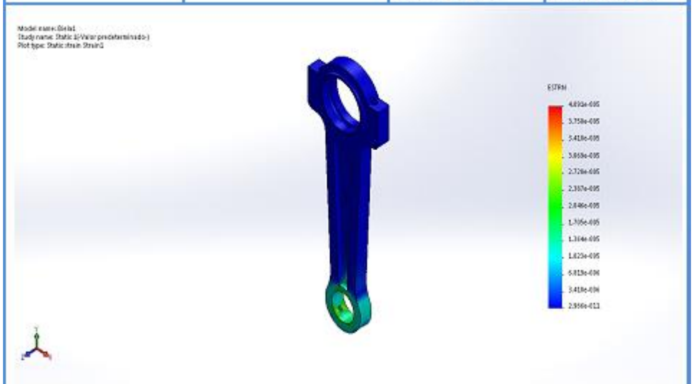
Biela1-Static 1-Displacement-Displacement1

Meshing model



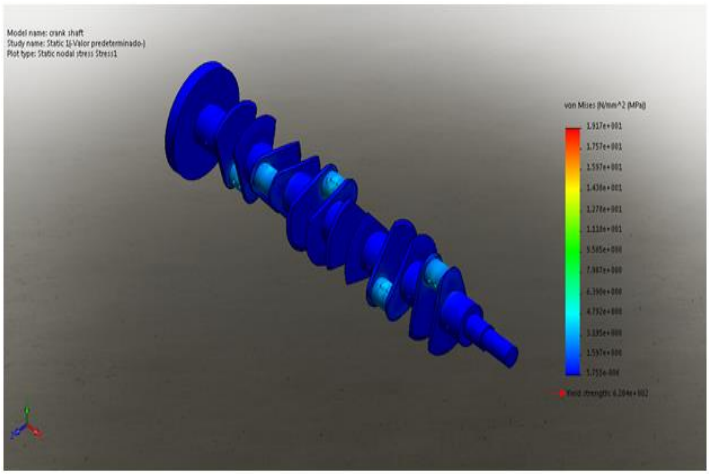
Strain

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	2.96583e-011 Element: 19592	4.09141e-005 Element: 11602



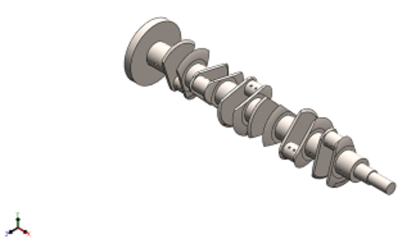
Biela1-Static 1-Strain-Strain1

Static stress



Static analysis on connecting rod

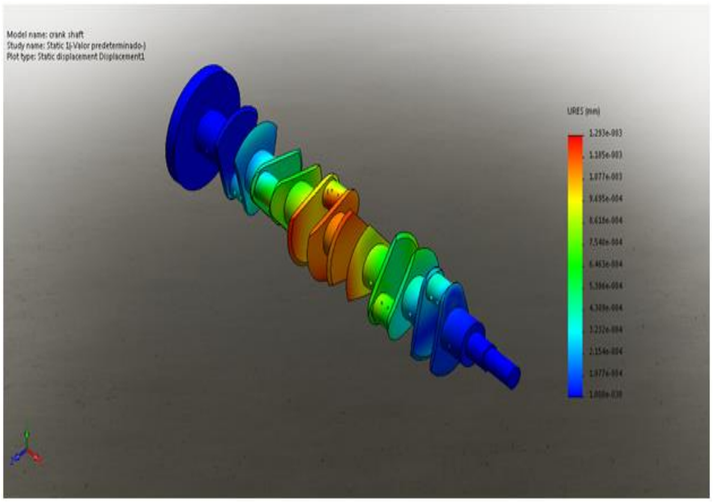
Model information



Model name: crank shaft
Current Configuration: Valor predeterminado

Solid Bodies			
<L_MdInf_SldBd_Nm>	Treated As	Volumetric Properties	Document Path/Date Modified
Filete2 	Solid Body	Mass:17.9459 kg Volume:0.00233064 m^3 Density:7700 kg/m^3 Weight:175.87 N	\\10.0.0.4\e\Mechanical\mail\v12\V12 part files\part files\crank shaft.SLDPRT Jan 21 14:49:01 2015

Total deformation



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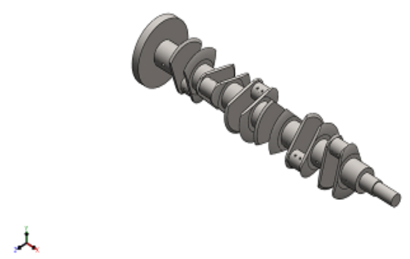
Static analysis on crank shaft (cast alloy steel)

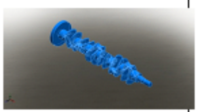
Model information



Model name: crank shaft
Current Configuration: Valor predeterminado

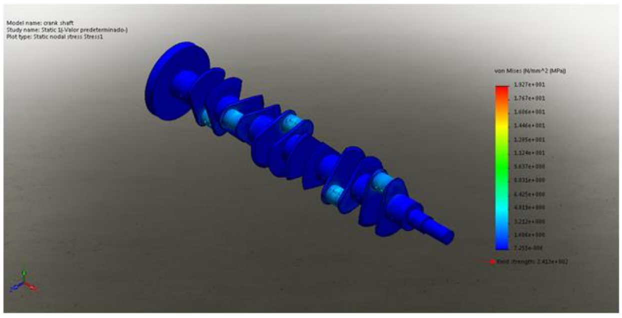
Solid Bodies			
<L_MdInf_SldBd_Nm>	Treated As	Volumetric Properties	Document Path/Date Modified
Filete2 	Solid Body	Mass:17.0137 kg Volume:0.00233064 m^3 Density:7300 kg/m^3 Weight:166.734 N	

Material properties:

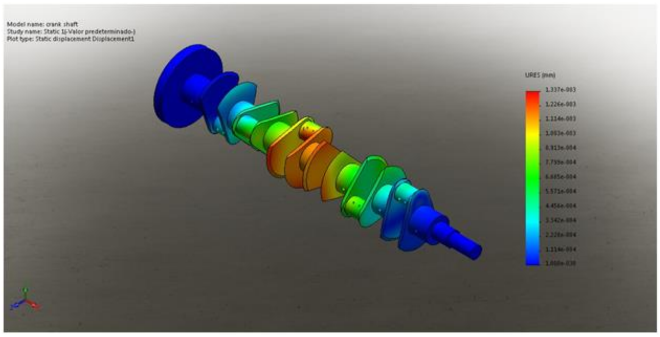
Model Reference	Properties	Components
	Name: **Cast Alloy Steel** Model type: **Linear Elastic Isotropic** Default failure criterion: **Max von Mises Stress** Yield strength: **241.275 N/mm^2** Tensile strength: **448.082 N/mm^2** Elastic modulus: **190000 N/mm^2** Poisson's ratio: **0.26** Mass density: **7300 g/cm^3** Shear modulus: **78000 N/mm^2** Thermal expansion coefficient: **1.5e-005 /Kelvin**	**SolidBody 1(Filete2)(crank shaft)**

Mesh model

Stress value



Deformation



Results

Static analysis results of piston

material	load	Stress(mpa)	Deformation(mm)
Alloy steel	1000	2942	0.09
Cast ally steel	1000	3060	0.1

Static results of connecting rod

material	load	Stress(mpa)	Deformation(mm)
Alloy steel	1000	12.21	0.0003
1023 steel	1000	12.20	0.00032

Static analysis results of crank shaft

material	Pressure (mpa)	stress (mpa)	Deformation(mm)
Alloy steel	3.5	1.9	1.293*10-3
1023 steel	3.5	2	1.3*10-3

Conclusion:

- Modeling and analysis of v12 engine has been done in solid works soft ware.
- Simulation has carried out on piston, connecting rod and crank shaft. With different materials respectively.
- After studied the result we can conclude that alloy steel has better load resistance and low deformation.

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