ISSN 2229-5518

Kinematic Design of a Variable Pitch Fan Actuator Mechanism for IC Engine

Prof. E. N. Aitavade, Prof. H. V. Shete, Mr. Mali P. R., Mr.Patil N .T., Mr. Tagare V. S.

Abstract-

In water cooled engines presently fix blade fan is used in radiator cooling .The drawback of present system is that when engine runs under high load sufficient cooling is not achieved which results in hydraulic over heating may damage the engine or lead to fire hazard. Also when engine is under loaded the fix blade fan over cools the engine and results in loss of power .This work aims to design and manufacture a control system to make use of variable pitch fan.

In today's economic scenario such a system plays very important role. There is much money invested in heavy duty equipment. The proposed work will offer total control of the air movement through the radiator with variable pitch reversible radiator fan. This system will solve the problems of overheating and over cooling in water cooled engines used for forestry, pulp and paper industry, mining, construction industries, earthmovers and extreme climatic conditions. The control system will automatically adjust the blade pitch to maintain optimum temperature. There are broad fields of application of this system in automobiles to increase cooling efficiency. Also variables pitch fan is efficient at different speeds which result due to load change. This is important when fan absorbs more power as in case of mine ventilation fans. In this paper various alternatives for the variable pitch fan mechanism are discussed followed by the convergence to the final mechanism. The Catia V5 models of the mechanisms are prepared and feasibility is discussed.

Key Words: I.C.Engine, variable pitch fan, control system, principle, applications, iterations, Catia V5

1.1 Introduction:

The internal combustion engine is a heat engine. The chemical energy of the fuel is converted into heat energy by combustion and this heat energy is intern converted into mechanical energy by the engine. Approximately one third of heat energy is converted in to mechanical energy; about one third is removed by cooling system and about one third by the exhaust system. For each 3.8 L of fuel burned, about 6.32 MJ must be rejected to cooling system. If this heat is not removed engine will be destroyed.

The cooling system consists of a radiator (heat exchanger), thermostat, coolant pump, coolant jacket surrounding the cylinders and combustion chamber and various rubber hoses serving as flexible connections between the radiator and engine to allow complete circulation of the coolant. The coolant pump circulates the coolant through jacket where it picks up heat dissipated by combustion chambers and cylinders and then through radiator, allowing the heat to be transferred to the outside air. This cycle continues. After world war II automobile manufacturers began building cars having high compression engines and more power. At the same time engine power was being increased, styling demands required the silhouette be lowered. This called for more compact arrangement of engine and cooling system components with result that the airflow through the radiator core tended to be obstructed. This problem was partially overcome by using pressurised cooling systems.

In 1937 some cars were produced with 28 kPa pressure cap which increases 7 °C increases in the coolant boiling point. In 1960 all liquid cooled cars produced in US had 90-117 kPa pressure caps on their radiators allowing a 19-24°C increase in maximum coolant temperature. Current cooling systems are limited to about 117 kPa pressure by the strength of solder used in radiator.

The maximum operation temperature is limited by the oil lubrication characteristics, predestination of the fuel and thermal properties of engine components and materials. For instance one constraint on thermal efficiency gains is the engine exhaust valves high operating temperature. To withstand their high temperatures which originate from the composition gases, the valve's material selection is predicted by mechanical and thermal properties that must allow it to withstand this harsh engine environment. Various alternatives are used to control engine temperature. Zthese are intelligent thermostat with solenoid control and intelligent CVT water pump.. An attractive alternative to these enhanced water pumps and intelligent thermostat is a **Variable pitch fan.**

As shown in figure an AC geared motor actuated variable pitch fan is mounted on the water pump shaft to maintain the same footprint as current fan.

The mechatronic variable pitch fan is integrated in engine management system to actively regulate air flow through radiator for customised heat transfer. The pitch control is achieved through a micro controller. The control algorithm will use a simple mathematical model to estimate the change in the pitch required at different loads at constant speed operation of engine.

The system consists of a temperature sensor (RTD-PT100) AC geared motor, variable pitch fan mechanism and relay circuit controlled by microprocessor.

Generally the scope of fan design is :

1. The design development will be confined to case where inlet and outlet conditions promote relatively uniform flow.

2. Design methods will be based exclusively on list, drag and deflection data from wind funnel tests on isolated cascaded aero foils.

1.2 Variable Pitch Fans

Principle and Various Mechanisms of Variable Pitch Fan:

This work aims at specific type of axial flow fan called 'variable pitch fan' which has provision for changing angle of attack of blade on high pitch or low pitch side.

It has applications in helicopter propeller fan, aircraft propellers, and ship propellers (for reversing of ship). Fan brake dynamometers.

There are various disadvantages in the operation of fixed pitch fans. When a fan is brought "off the shelf" , the rotor must be run at a certain rotational speed , specified by the makers , if the desired values of pressure rise and capacity are to be realised.

The use of variable pitch fan blades has introduced area of greater flexibility in the operation of ducted axial flow fans. A given pressure rise and the accompanying capacity can now be achieved with the aid of an additional variable. For example, the rotor speed of a particular configuration can be changed to a more convenient value and the blade pitch altered so as to keep the operating requirements unchanged. A large increase in the non-dimensional duct resistance, due to additional duct elements, can also be dealt with by the experiment of reducing the blade setting angle relative to the plane of rotation; an increase in rotor speed will then permit the original capacity to be reproduced.

In case of mine ventilation fans, an increase of 2 or 3 percent in efficiency can represent an extremely worthwhile reduction in the mine running expense. Variable pitch greatly extends the operating range over which high efficiency can be obtained and it is in this respect that such fans attract most attention. The additional capital cost is soon offset by the savings affected through increased efficiency.

Two types of configuration, in ascending order of complexity, are listed below.

(i) A "Standard" blade is designed for a rotor of given boss and fan diameters. For a specific task, the correct number of blades is permanently fixed to the boss at the desired pitch angle. When a change in fan duty occurs, the blade pitch is altered by substituting a different rotor. This method avoids the mechanical complication of adjustable pitch and may provide a cheap solution

(ii)In some instances it may not be practical to stop the fan in order to change pitch, in which case suitable manual or automatic mechanisms must be provided.

The first type of unit is the most popular, since the mechanical complications are by no means excessive.

Controllable Pitch Propellers:

As the name implies, a controllable-pitch propeller is one on which the blade angle can be changed while the aircraft is in flight. Propellers of this type have been used for many years on aircraft where the extra cost of such a propeller was justified by the improved performance obtained.

Advantages:

The controllable pitch propeller makes it possible for the pilot to change the blade angle of the propeller at will in order to obtain the best performance from the aircraft engine. At take off the propeller is set at a low blade angle so that the engine can attain the maximum allowable rpm and power. Shortly after takeoff the angle is increased slightly to prevent over speeding of the engine and to obtain the best climb condition of engine rpm and airplane speed. When the airplane has reached the crushing altitude, the propeller can be adjusted to a comparatively high pitch for a low cruising rpm or to a lower pitch for a higher cruising rpm and greater speed.

Two-Position Propeller:

A two-position propeller does not have all the advantages mentioned in the foregoing paragraph , however , it does permit a setting of blade angle for best takeoff and climb (low-pitch , high rpm) and for best cruise (high-pitch , low rpm).

One of the best-known two-position propellers was manufactured by the Hamilton-Standard Propeller Division of the United Aircraft Company. This propeller was used extensively for training.

The principal parts of this assembly are the hub assembly, and the cylinder and piston assembly. The blade angle is decreased by the action of the cylinder and piston assembly when engine oil enters the cylinder and forces it forward. The cylinder is linked to the blades by means of a bushing mounted on the cylinder base and riding in a slot in the counterweight bracket. As the cylinder moves outward, the bracket is rotated inward, and since the bracket attached to the base of the blade, the blade is turned to a lower angle.

Initial horizontal balance of the two-position counter weight type propeller is adjusted by balancing washers installed in the base of the blades. Initial vertical balance is accomplished by means of balancing washers installed in the space provided in the barrel supporting block inside the hub barrel. Final balance is adjusted by installing lead wood in or removing it from the hollow assembly bolts.

1.2.1 Axial Flow Fan Applications:

The various applications of axial flow fans can be enumerated as follows -

a. Power Plants: Forced draft and induced draft fans are used to raise the pressure of air and flue gases necessary to overcome the draft losses in the flow passages of a steam boiler plant. The pressure rise is about 200 to 800 mm W.G.

b. Cooling towers: Large quantities of the condenser circulating water are cooled in cooling towers. The degree of cooling achieved in this cooling tower is independent of the ambient conditions. (Temp & humidity). Fan for this application are generally of a large axial type, developing a low pressure rise and higher air flow rates.

c. Cooling of motors, generators and engines: Considerable quantities of heat need to be removed from I.C. engines, and electrical motors and generators. Another example is the cooling of the automobile jacket hot water in radiator by using the fans.

d. Air circulation and mine ventilation: Fans of various versions are used to circulate air in air-conditioning systems.

e. In steel plants: Larger and small fans or blowers are employed in a number of applications in steel plants. One or more high pressure blowers are employed to supply blast furnace gases to the steam boilers.

1.3 New variable pitch fan:

New fan will be with variable pitch blades. The angle of blades is controlled through AC geared motor through 8031 microcontroller and RTD (PT100) temperature sensor. The system is as shown in fig. 1 .Three iterations are done to develop the mechanism.

The first iteration was a mechanism (fig 2) using pin and a grooved shaft actuator. The drawback was low strength of pin and lot of friction.

The second iteration was a mechanism which uses a slider crank chain and a common piston as shown in fig 3. This resulted in lot of weight and unsatisfactory operation due to less precise workmanship and was rejected.

The third mechanism as shown in fig 4 uses bevel gears is selected as it is compact, and has less moving parts.

Another advantage is that of possibility of giving rotary signal is there at the shaft of mechanism. Important feature of this mechanism is control motor slip rings. As motor is required to rotate with mechanism it is supplied the voltage through a slip rings. The motor is embedded in the nylon bar on which slip rings are mounted and supply is given through these slip rings to control blade angles.

1.4 Control System:

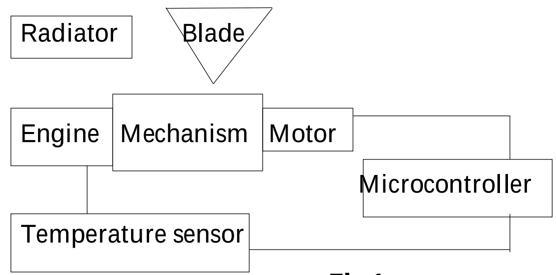

Fig 1

1.5 Mechanism Design and CATIA V5 Models

1.5.1 First Iteration:

In this mechanism (fig.2.1, fig.2.2) the threaded shaft is inserted in to the hollow shaft supported on two brackets. The threaded shaft is rotated by hand or using any power drive. At the end solid shaft one groove is provided. There is rotating disk engaged with solid shaft by using pin. The rotating disk connected to the blade base.So on one hollow shaft number of blades are attached equispaced at 90^0 (four blades), 120^0(three blades). Bush is provided for guiding the blade.

The gear is provided for giving motion to the fan by meshing with another gear and the handle is operated for changing angle of blade ,according to requirement of air flow. When the handle is operated, grooved shaft moves inward. Then disk rotates and due to pins in turn changes the angle of blade.

ISSN 2229-5518

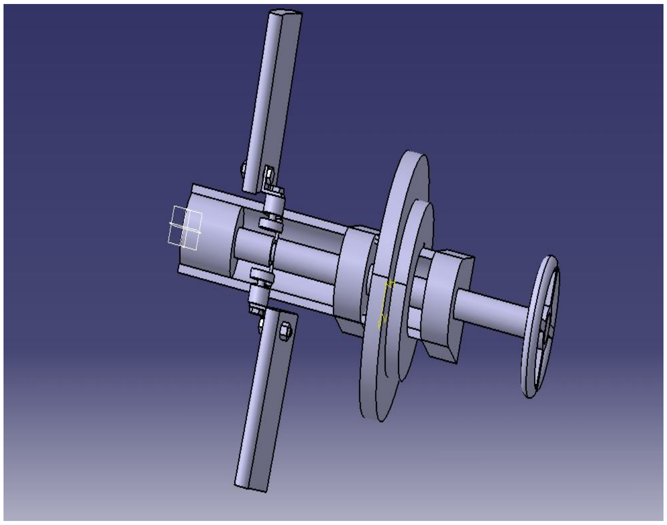

Fig 2.1

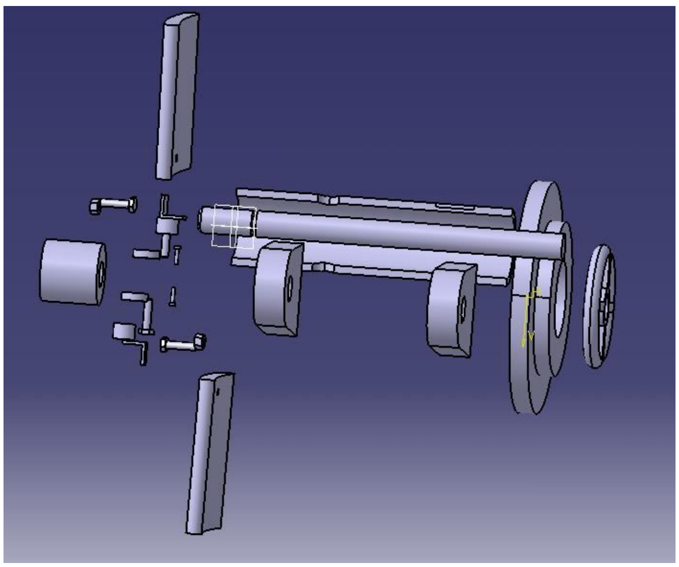

Fig 2.2

1.5.2 Second Iteration:

In this type of mechanism (fig 3.1, fig 3.2) linear motion is converted in to rotary motion .In this mechanism hollow shaft is mounted on flange of the engine, which can be rotated by the engine. Hollow shaft contains common piston which has to and fro motion. The common piston is spline fitted in hollow shaft. When hollow shaft rotates, to and fro motion of common piston is takes place by using servo motor having variable speed. This actuates six connecting rods engaged with it by pin joint. Other end of the connecting rod is fixed with crank and there is only turning pair between connecting rod and crank.

Sliding motion takes place only when motion of servomotor shaft takes place. When crank rotates the fan blades are rotated according to requirement.

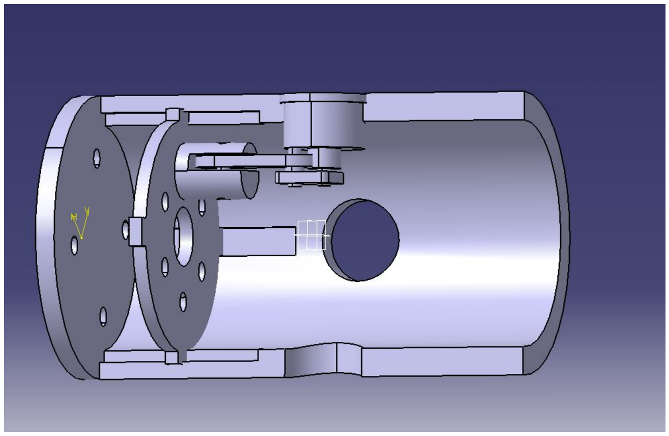

Fig 3.1

.

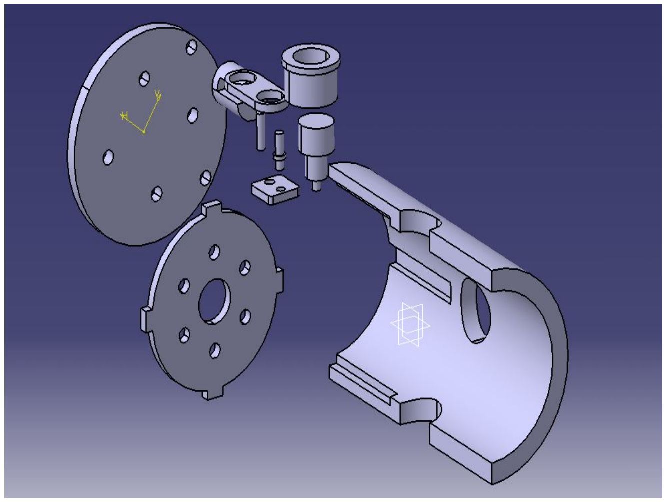

Fig 3.2

1.5.3 Final Mechanism:

The mechanism is shown in (fig4.1, fig4.2). Electric AC supply is given to the ac geared motor .The motor shaft is connected to gear shaft .When motor rotates, power is transmitted to Gear1. Gear1 and Gear2 are in mesh with each other. Due to this Gear1 transmits power to gear2. Gear2 and Gear3 are placed on same shaft .Similarly Gear3 and Gear4 are engaged with each other. From Gear3 to Gear4 the power will be transmitted to differential input shaft gear train.

The Gear5 and Gear7 are on same shaft. They rotate with same speed. But when AC geared motor rotates, the gears 5 and 7 will rotate. These gears will in turn rotate the pinions on the shaft of which the blades are attached. The signal for motor is given through the slip rings. This is the special features of this mechanism. The mechanism consists of all rotary members so is quite stable and balanced. Hence this mechanism overcomes the over weight problem of second iterations and pin failure problem of first iteration. During engine testing no imbalanced and failure problems were noticed in the mechanism.

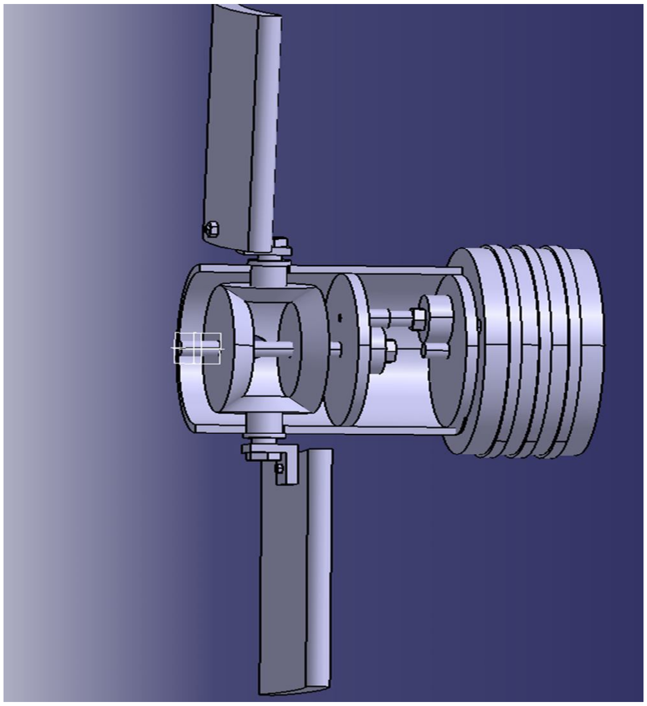

Fig 4.1

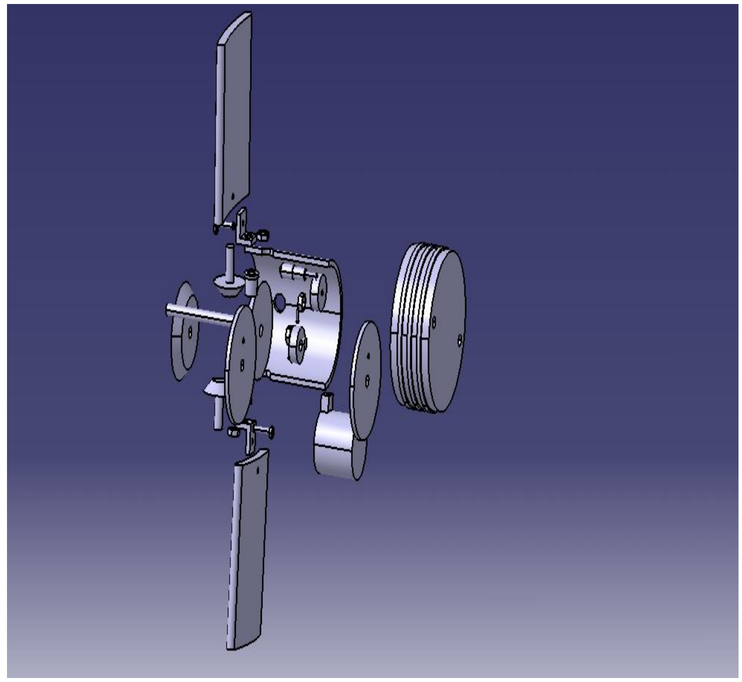

Fig 4.2

1.5.4 Advantages of using variable pitch fan in IC Engine:

1. Maximum temperature of operation of engine is reduced which avoids engine overheating and improves life of engine. Due to low operating temperature engine fatigue life is also improved as well as thermal stresses are minimise as engine remains at set point temperature
2. Control system can be developed so as to keep engine at maximum thermal efficiency resulting in improved fuel consumption.
3. Lubrication characteristic are improved due to low operating temperature which leads to improved engine life less frictional power loss low lubricating oil consumption per year
4. This will leads to reduced down time and improved productivity of engine and economy.

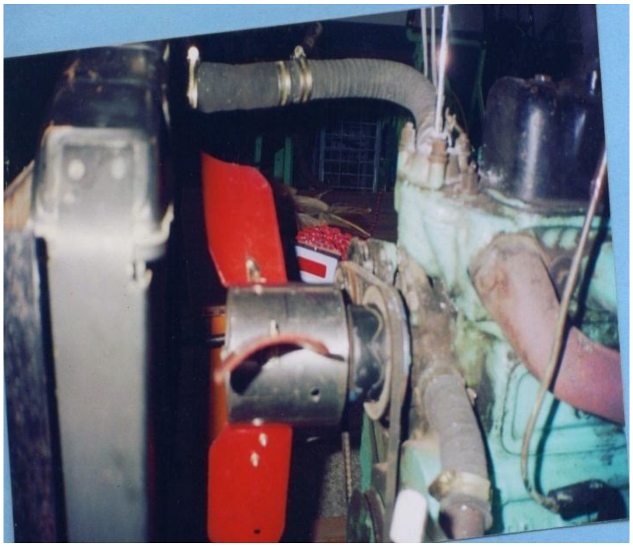

Plate 1 - Working model of final iteration

1.6 Conclusion:

With reference to the series of tests carried out on engine it is observed that the variable pitch fan is an attractive alternative to the fixed blade fan, as the engine irrespective of load is maintained at set point temperature with 10% to 20% variation depending on control system characteristics. The final iteration is more suitable than first and second iteration. Hence final iteration is practically easy to manufacture and so more suitable. In future scope for dynamic analysis of mechanism can be done and validated.

References:

[1] Artobolevsky, "Mechanisms in Modern Engineering Design" MIR Publishers.
[2] R.A.Wallis (1961) "Axial flow fans - Design and practice,Newones, London.
[3] A Kolchin and V. (1984) " Design of Automotive Engines" ,Mir publishers (SI units)
[4] Wagner J.*et al* (2002). "Enhanced automotive engine cooling systems - a mechantronics approach," Int J of Vehicle Design Vol 28, Nos 1/2/3, pp 214-240.
[5] J.A Cook *et al*, "Automotive control systems , (The Control Hand Book) , Crc Presses , IEEE press , section XVI , chapter 74 , pp 1261-1285.
[6] Eitavade E.N. and Phadnis A. M. (1992)"Variable pitch fan", a project report for BE Mechanical.
[7] Peatmann, "Design with microcontrollers"
[8] Sean Bennett (1998) "Medium /heavy duty truck engines, fuel and computerized management systems", Delmar.
[9] Bent McKinley,"Aircraft power plants"
[10] Shingley," Theory of machines and mechanisms ".Mc Graw Hill.

- ***Prof. E. N. Aiatvade is currently working as Assistant Professor in Mechanical Engineering at Tatyasaheb Kore Institute of Engineering& Technology, India- 416113, PH – 09922848887. E-mail: enaait@yahoo.co.in***
- ***Prof. H. V. Shete is currently working as Associate Professor in Mechanical Engineering at Ashokrao Mane Group of Institutions, India- 416112, PH – 09823925440. E-mail: sheteaditya@yahoo.co.in***
- ***Mr. Mali Pritam R., Mr.Patil Namdav T., Mr. Tagare Vikas S. are studying in final year of Mechanical Engineering at Tatyasaheb Kore Institute of Engineerring & Technology, India-416113.E-mail:namdevtpatil@gmail.com, pritamrmali@gmail.com,*** vikastagare05@gmail.com