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Design and Fabrication of a Model Jet Engine (Sivani 150)

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ABSTRACT:- Gas turbines have long since claimed a secure place for themselves in our world. Amongst the most obvious examples are the innumerable aircraft which day after day fly above us, but that's not all; gas turbines are at work where you might not know it; nowadays they are used more and more commonly in power stations, electricity generators, boat engines and much more. Suddenly these engines are increasingly being used to propel models, and that is why we need to understand how they work and how they can be manufactured. Turbine engines produce thrust by increasing the velocity of the air flowing through the engine. This paper summarizes working, designing, fabricating and testing a model jet engine.

Index Terms:- model jet engine, fuel selection, metal selection, design, fabrication, testing

I. THEORY OF OPERATION

In an ideal gas turbine, gases undergo three thermodynamic processes: an isentropic compression, isobaric (constant pressure) combustion and an isentropic expansion. Together, these make up the Brayton cycle.

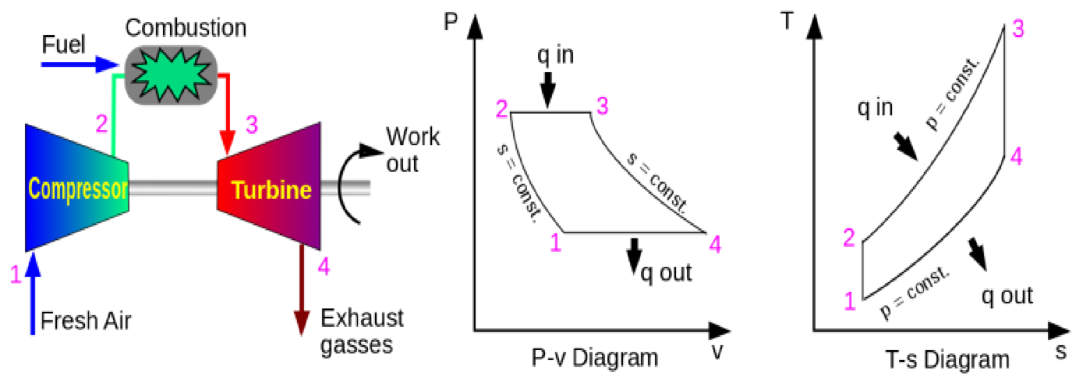

Fig.1 Brayton cycle

II. SIMPLE JET ENGINE WORKING

The turbo-jet requires two separate stages, namely the compressor stage and turbine stage. Each of these stages consists of diffuser blades plus a revolving rotor, the compressor and turbine wheels-which are coupled to the shaft. The sub assembly consisting of shaft, compressor wheel and turbine wheel is termed the rotor heat energy added in the combustion chamber, through which the whole of the airflow streams. The combustion chamber is located between the compressor and turbine stage.

They are insatiable fuel consumers. The more they get, higher the thrust, temperature and rotational speed. At the same time efficiency of energy conversion process also increases, and with it the rate of speed increases. If the fuel supply is not restricted, the turbine's speed races away until one or other rotating part can no longer withstand the centrifugal load. The supplementary energy is also required for ignition. In contrast to a piston Engine, combustion in a gas turbine is a continous process, so the mixture only needs to be ignited once.

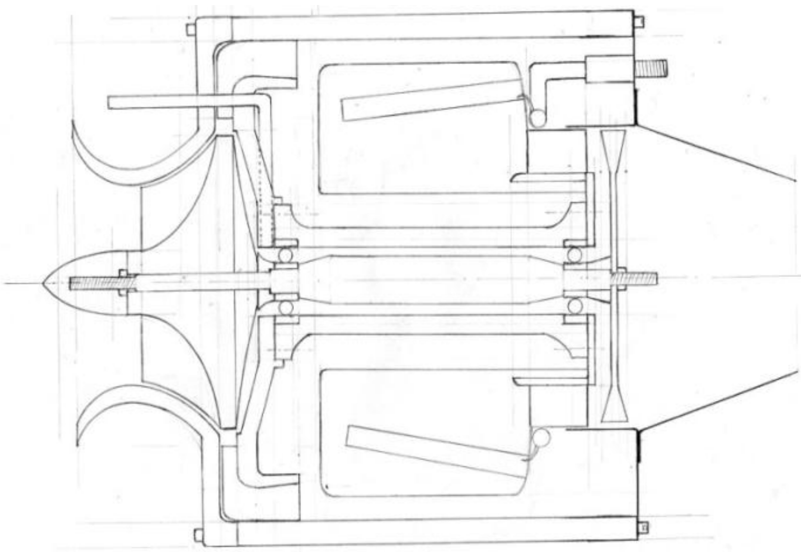

Fig.2 Model jet engine cross-sectional view (our design)

III. MODEL JET ENGINE PARTS

3.1. RADIAL COMPRESSOR

The purpose of the compressor is to compress the air drawn into the engine. The basic principle of all compressors is the same it converts kinetic energy into pressure energy. To achieve this air drawn into the compressor is first accelerated to high speed and then decelerated. This action converts the speed of the gas into pressure. If radial compressor is used, centrifugal force provides a further increase in air pressure.

For the modeller the compressors incorporated in turbochargers are an ideal starting point for the construction of a model jet engine. Good wheels of around 60mm diameter achieve efficiencies between 70 and 75%, while larger versions approach 80%. The compressor used in our model is 83mm diameter taken from a lorry turbocharger.

Fig.3 Radial compressor

3.2. COMPRESSOR GUIDE VANES OR DIFFUSER SYSTEM

In the compressor diffuser system the residual speed energy in the flow is converted into pressure energy. A particularly critical point here is the area immediately behind the rotor wheel, where flow speeds are still high. The diffuser system in this area must be matched very accurately to the rotor wheel. If a bladed diffuser system is used the blades must be designed in such a way that they start exactly in the direction of the flow. A variation in the flow angle of only a few degrees may mean that the model jet engine refuses to run. It goes without saying that obstacles to the gas, such as pipes and retaining bolts, must be kept away from this area.

The diffuser system is machined from a solid aluminium rod on a lathe machine as per the dimensions. Aluminium is the best metal for compressor guide vanes system as the temperatures of the engine at this point is low and to reduce the engine weight. Initially it is machined on the lathe machine to obtain the shape as shown in the design side view. Later 18 slots with an angle of 21degrees are made using a copping saw. Cut out the diffuser blades from 1 mm thick aluminium sheet metal and fix those in the slots using apoxy resign. And three holes are drilled as per the design to fix the shaft tunnel. Air ducts for cooling the bearings must be machined in at the point where the shaft tunnel meets the holder. Each duct is 5 mm wide and is located between a pair of adjacent mounting screws. The ducts should be one millimeter deep-this is quite adequate.

Fig.4 Compressor guide vane system machining

A small proportion of compressed air from the compressor enters these ducts, and at the same time some of the fuel oil mixture is blown in with it. The air flows through both bearings and leaves the shaft tunnel at the rear.

3.3. SHAFT

Heat treated steel is should be used to make the shaft. A proven method is to make the shaft components from large machine screws with a strength rating of 12.9 these are generally alloy steels. The pushrods are often case hardened, which means that the thin hardened, removed before turning using grinder. The shaft material must be tough, but not brittle. The shaft simply must not break. The modulus elasticity of various types of steel varies very little. And as a result the bending at critical speed for all shafts is about the same. Stainless steel is not a suitable material for turbine shaft. As a conductor of heat, standard commercial stainless steel is around four times worse than low alloy steel, and therefore the heat from the hot turbine wheel is not desisted quickly enough.

Our engine shaft is machined on a lathe machine from a 12.9 graded steel rod. The shaft length is 196mm. initially it is advisable to make the shaft 5 to 10mm longer than stated to give you scope for correcting any inaccuracies. The first step is to rough turn the shaft on the lathe. For the best results use turning tools with a tungsten carbide cutting tip. All fits should be left clearly oversize. The threading on both sides of the shaft is machined with a 6mm die. The spacer discs should be considered as the part of the shaft. Two are required: one at the compressor, the other at the turbine wheel.

Fig.5 Shaft with bearings and spacers

3.4. SHAFT TUNNEL AND BEARINGS

The shaft tunnel is made of aluminum rod. The ball-race at the compressor end should be a good press-fit in bearing seating, and the bearings should end exactly flush with flange .in contrast, the turbine end bearing housing must be oversize in order to allow for the differential expansion odd shaft and tunnel. Since the bearings operating temperature is high. If the rear bearing is slightly tight when cold this is no cause for anxiety. The thermal expansion of aluminum is greater that of steel, so the correct clearance will develop when the parts running temperature.

The bearing configuration used in this design assumes the use of standard ball races of model no. 609Z. The bearings with rolled brass cages are not suitable hybrid bearings with silicon nitrate balls offer a virtually unlimited life. The final part of the shaft tunnel is the lubrication system. The oil pipe is made from thin brass tubing, bent to the share. The oil pipe is clamped in place in one of the three air ducts when you screw the shaft tunnel to the compressor diffuser vane system. The shaft tunnel should be held in place using high-strength screws, perfectly socket head types, and thread lock fluid. The other end of the tube exits the engine through a hole in the compressor cover.

Fig.6 Shaft tunnel with bearings

Shaft tunnel is also machined on the same lathe machine as it is an axis symmetric job. Apply kerosene as coolant while machining aluminium for smooth finishing. Initially drill a hole of 18mm diameter throughout the rod. Next boring operation for bearing seating as per the dimensions mentioned in the diagram. Drill three holes on both sides of the bearing flanges to hold it in a place using high strength screws.

3.5. THE COMBUSTION CHAMBER AND FUEL INJECTOR

If combustion is uneven the inflowing air not beaded to full temperature in certain area of the combustion chamber .The enthalpy of this portion of the air only rises slightly, and in consequence does little work. When flowing through the turbine stage. To compensate for this deficit the rest of the air must become that much hotter when it flows through the turbine. This uneven temperature distribution results in uneven speed distribution in the turbine nozzle guide vanes and thus poor overall efficiency in the worst case this simply means that the model jet engine will not run at all.

Fig.7 Combustion chamber

In principle the jet engine is not confined to a particular type of fuel. The main requirement is that the maximum quantity of energy is released during combustion. In practice most jet engines are designed to run on one of the many mineral oil products which are commercially available.

The most promising route to instant success is to use gaseous fuels such as propane or butane. No fuel pump is required as the pressurized gas flows into the model jet engine naturally. Mixing the gas with air is also relatively straight forward. Usually all that is required is few injection openings distributed around the combustion chamber. The flow of pressurized gas draws sufficient air in with it to produce a combustibles mixture.

This is made of thin stainless sheet steel. The ideal material to this component is 0 .3 mm thick sheet and this should be used if available otherwise you can use the more widely available O.5 mm thick sheet. The curvature of the combustion chamber cover produces a smooth. Rounded geometry in the primary Zone and this helps to eliminate dead areas in the air at low, and unburned fuel is re-turbinated more quickly. The outer jacket and combustion chamber inner section should fit together with little play.

Fig.8 Fuel injector

It is up to you whether you bore the holes first then weld the parts together or vice versa. In either case all the holes which are larger than 1mm diameter should be opened up slightly using a die and punch. Each stick is made from a 70 mm length of tube, which is first belled out at one end to 8 mm diameter. These tubes act like vapourisers in the combustion chamber. The last part to make is the injector ring. It is made from a copper tube by heating and bending slightly until the tube forms a ring shape.

The injector tubes are made from size 2 syringe needles. These are fitted into the injector ring tip-first, and silver soldered in place.

3.6. TURBINE

The combustion gas flows first into the turbine nozzle guide vane system. Where the blade ducts work like small jets. Accelerating the gasses in the direction of rotation of rotor. At the same time the gas expands. As pressure and temperature fall, speed rises rapidly. At this point the gas strikes the turbine blades. Since turbine wheel already spinning at very high speed.

The actual wheel is made of 2mm thick sheet metal. Cut out a suitable blank and bore the central hole for the shaft. Heat-resistant steel should be bored out in stages using a low rotational speed and cutting fluid. Use a reamer to open up the hole to the exact size. Tungsten carbide tipped cutting tools have proved a good choice for this task. Leave the wheel diameter about 1 mm oversize. The next step is to saw the 19 blades down to a diameter of 16 mm. An ordinary hacksaw fitted with an HSS blade has proved suitable for this job.

Heat the turbine blades to red heat using an annealing process, then twist them in the clockwise direction through 30 to 35 degrees using a pair of pliers or a home-made claw tool. The final blade angle is established when the turbine blades are ground to shape. This is done using a disc cutter clamped in a drill press. The first step is to continue the saw cuts down to the final dimension of 44 mm hold the turbine wheel at an angle of about 35 ° to the disc cutter and grind through to the final dimension. Finally check the tip angle of each turbine blade should be 34 degrees.

Fig.9 Turbine machining

3.7. THE NOZZLE GUIDE VANES SYSTEM

The nozzle guide vanes system for the turbine is one of the most complex parts of the engine. It has two primary functions .feeding the gasses to the turbine wheel and providing a location for the shaft tunnel .the mounting flange to the housing also serves as a burst shield.

The first step is to make the inner ring. It can either be turned from a suitable piece of tube or bent to shape from sheet metal. Mark the eleven blade slots as shown in the drawing and saw them out using a piercing saw. You may need to shorten the saw blade (hard metal grade) to prevent it fouling. If you have any choice, select a good heat-resistant material for the nozzle guide vane blades but otherwise use stainless steel. Cut out the blades leaving them well oversize, bend them to approximate shape, and then place them in the inner ring. If you look at the guide vane system from the front, the vanes should overlap each other as far as possible. Finally weld the blades and the blank disk in place from the inside using an electric welder. Then tap three holes to attach the nozzle guide vanes system to the shaft tunnel.

Fig.10 Nozzle guide vanes system machining

3.8. COMPRESSOR COVER AND CASING

Compressor cover is machined from a solid aluminium rod on lathe machine. Initially clamp the rod to the lathe chuck and bore a 40mm hole throughout the rod. Then giving small steps and finishing them with file or finishing paper, maintain the curve of the radial compressor. Check it repeatedly putting the compressor wheel in the hole. Outer conical shape can be obtained by tapper turning operation.

Fig.11 Compressor cover machining

The housing or casing is made up of aluminium pipe outer diameter of 150mm & inner diameter of 136mm; it is machined on the lathe machine as per the dimension. Totally 16 taps are machined on both faces of the pipe, to fix the compressor cover & exhaust cone.

3.9. THE EXHAUST CONE

This is made from a brass sheet. This is placed on the rare side of the jet engine. It acting like a convergent nozzle and increases the thrust. It is machined by using gas welding, brass as filler metal. Initially cut the required shapes from a 0.5mm thick brass sheet. Then bend them into conical shape and circular disk and weld both the parts. Finally drill 3mm holes around the cone to clamp the exhaust cone to the casing.

Fig.12 Exhaust cone with heat resistant gasket

IV. ASSEMBLING THE COMPONENTS

The individual components are assembled as show in the assembly drawing. The shaft tunnel, compressor diffuser system, rotor, nozzle guide vane system and combustion chamber form one sub-assembly as shown in the below figure. The compressor cover is attached to the compressor guide vane system using three self-locking nuts which should be tightened no more than hand-tight. Then the casing and exhaust cone are assembled with Allen screws.

Fig.13 Interior assembly

It's better to place metal gaskets between the casing and compressor cover and at exhaust cone to prevent the gas leakage and compressed air leakage.

Fig.14 Model jet engine with pressure guage

V. TESTING WITH PROPANE GAS

Initial test runs of your new model jet engine should be made using propane gas. Propane is ideal for testing since it burns well in the combustion chamber and is easy to meter. If possible use a 5kg propane bottle in conjunction with the matching solder gun attachment. Smaller bottles and gas cartridges will give you problems starting your turbine; the system must be capable of supplying full gas pressure. Fittings for camping Apparatus are just not up to the job. Run the gas to the kerosene feed connection. To start the engine you will also need a starter fan or compressed air.

Vacuum cleaner fans have proved excellent starters. Other equipment you will need includes a U-tube filled with water to measure compressor pressure. This should be connected to an unused pressure Nipple in the housing. One centimeter of water column corresponds to one Mille Bar i.e. O.OO1 Bar.

VI. MEASURING ROTATIONAL SPEED

The maximum permissible rotational speed of our turbo-jet engine is 75,000 rpm. Special tachometers reading up to 100,000 rpm are available through specialist dealers. It is impossible to operate a turbo-jet successfully unless you can measure its rotational speed.

VII. MEASURING PRESSURE

The ability to measure pressure is useful in two areas of the system: To check the pressure of the fuel pump a manometer with a range of 10bar is enough, to measure the pressure at the compressor stage of the turbo-jet. In our design this pressure is a maximum of 0.5bar. A manometer with a measuring range of 1 bar is just right for this. Measuring pressure at this point is a useful means of checking how the engine functioning when you measure its rotational speed.

VIII. MEASURING THRUST

The thrust of a turbojet is undoubtedly the figure which interests us most. A set of domestic kitchen scales with a spring movement makes an excellent thrust meter. This can simply the anchored down on its side, and the fixed to mobile carriage, allowed to press against the scales. The scale of the thrust meter should read up to 5 or 10kg. A spring balance could certainly be used instead of the kitchen scales. Just connect the balance to the test rig of the model, outside the exhaust stream. Our engine produces 60 to 70 N thrust.

IX. CONCLUSION

The project carried out by us made an impressive task in the aeronautical industries and power plant industries. According to our research, when the compressor and turbine diameter is increased then the thrust produced by the engine is also increased. To verify that we increased the diameter of the compressor and turbine wheels and designed a model jet engine according to that.

To minimize the weight of the engine we are using single fuel pump for lubrication and fuel supply as the same oil can be used for both. The engine we fabricated is less expensive compared to the others. And our engine produces 50,000 to 75,000 rpm and 60-70 N thrust, which is more than the engine we referred.

X. FUTURE SCOPE

The main reason of researching and fabricating a model jet engine is to mount that engine to an aero model or any other future models which are going to be designed and fabricated sooner or later. As the jet engines are the one and only powerful engines that’s why we selected them for our future models. In future it will be attached to a helicopter and a hover board.

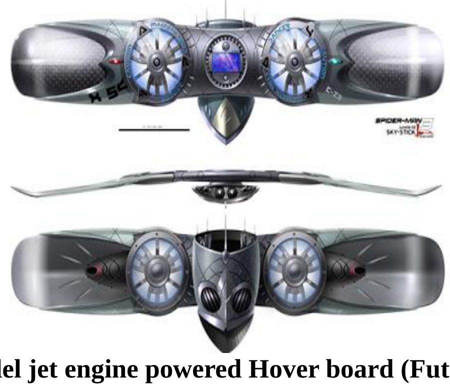

Fig.15 Model jet engine powered Hover board (Future model)

Fig.16 Application of Hover board (Future model)

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