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| |  | | --- | | **Experiment 6** | | **Performance of centrifugal compressor** | |
| |  |  |  | | --- | --- | --- | | 1. **Objective**  |  | | --- | | The objectives of this experiment are:  1. To understand the working of a centrifugal compressor.  2. To find the performance characteristics of the centrifugal compressor by conducting experiments. Plot performance curves and compressor map. | |  | | | 1. **Introduction**  |  | | --- | | Centrifugal flow compressors, sometimes referred to as radial compressors, are a special class of radial-flow work-absorbing [turbo-machinery](http://en.wikipedia.org/wiki/Turbomachinery) that include pumps, fans, blowers and compressors. The earliest forms of these dynamic-turbo machines were pumps, fans and blowers. What differentiates these early turbo machines from compressors is that the working fluid can be considered incompressible, thus permitting accurate analysis through [Bernoulli's equation](http://en.wikipedia.org/wiki/Bernoulli%27s_principle). In contrast, modern centrifugal compressors are higher in speed and analysis must deal with compressible flow. In an idealized sense, the dynamic compressor achieves a pressure rise by adding kinetic-energy/velocity to a continuous flow of fluid through the rotor or impeller. This kinetic energy is then converted to an increase in static pressure by slowing the flow through a diffuser.  http://images.books24x7.com/bookimages/id_15431/fig490_01.jpg  **Figure 10.1 Centrifugal pump**  Advantages  Centrifugal compressors are used throughout industry because they have fewer rubbing parts, are relatively energy efficient, and give higher airflow than a similarly sized [reciprocating compressor](http://en.wikipedia.org/wiki/Reciprocating_compressor) (i.e. positive-displacement). Their primary drawback is that they cannot achieve the high [compression ratio](http://en.wikipedia.org/wiki/Compression_ratio) of reciprocating compressors without multiple stages. Centrifugal fan/blowers are more suited to continuous-duty applications such as ventilation fans, air movers, cooling units, and other uses that require high volume with little or no pressure increase. In contrast, multi-stage reciprocating compressors often achieve discharge pressures of 55 to 69 MPa. One example of an application of centrifugal compressors is their use in re-injecting natural gas back into oil fields to increase oil production.  **Applications**  Centrifugal compressors are often used in small [gas turbine](http://en.wikipedia.org/wiki/Gas_turbine) engines like APUs (auxiliary power units) and smaller aircraft gas turbines. A significant reason for this is that with current technology, the equivalent flow [axial compressor](http://en.wikipedia.org/wiki/Axial_compressor) will be less efficient due primarily to a combination of rotor and variable stator tip-clearance losses. There are few single stage centrifugal compressors capable of pressure-ratios over 10:1, due to stress considerations which severely limit the compressor's safety, durability and life expectancy.  Additionally for aircraft gas-turbines; centrifugal flow compressors offer the advantages of simplicity of manufacture and relatively low cost. This is due to requiring fewer stages to achieve the same pressure rise. The fundamental reason for this stems from a centrifugal compressor's large change in radius (relative to a multi-stage axial compressor); it is the change in radius that allows the centrifugal compressor to generate large increases in fluid energy over a short axial distance.  Centrifugal compressors are used in applications requiring pressurized air at high flow rates. Some of the applications are cooling systems, burner air supply for furnace applications etc. | | | 1. **Equipment**  |  | | --- | | Armfield FM42 Centrifugal Compressor Demonstration Unit  Armfield WD7 Interface Device  Compatible PC (not supplied) running Armfield FM42-304 software  http://www.discoverarmfield.co.uk/data/fm42/images/fm42.jpg  **Figure 10.2 Centrifugal compressor experimental set up** | | | 1. **Pre-Lab**  |  | | --- | | What is the difference between a reciprocating and rotary compressor?  What are the advantages of rotary compressors over reciprocating compressors? | | | 1. **Operating Instructions and Procedure**  |  | | --- | | Check that the sensor and power leads from the FM42 are connected to the sockets on the front of the IFD7.  Check that the IFD is connected to a suitable mains supply, and check the socket on the front is connected using the lead provided to a suitable PC. Check that the red and green indicator lights on the front of the IFD7 are illuminated.  Run the Arm field FM42-304 software on the PC, and check that the software indicates ‘WV: OK’ in the bottom right-hand corner of the window.  Switch on the mains supply to the WV?, and switch on the WD7 using the power switch on the front. Check that the power switch on. Check that the green watchdog indicator on the mimic screen is illuminated. Switch on the compressor using the ‘Power On’ button on the software mimic diagram screen.  Check that the sensor readings on the software screen give sensible values. The pressure readings should be zero when the compressor is not moving. The temperature should be sensible given the ambient conditions in the room (typically between 15 and 30 ‘C). Zerothe pressure sensors if necessary using the ‘Zero’ buttons on the mimic screen, Read through the experiment before starting, to familiarize yourself with the procedure. Set the compressor speed to maximum (100%) and note but do not record the flow rate. Fully close the outlet aperture to give minimum flow. Click the button on the toolbar to record a set of readings. Using the maximum air velocity as a guide, select incremental values for air velocity that will give 10-15 individual steps between minimum and maximum velocity. | | | 1. **Working sheet**  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Sl.No | Inlet temperature0C | Orifice pressure  Pa | Compressor differential pressure, Pa | Fan Speed | Torque  N.m | | 10 readings for different flow rates |  |  |  |  |  | | | | 1. **Calculations**  |  | | --- | | Compressor discharge  Q is the flow rate of air, m3/s  Cd is the coefficient of discharge of the orifice (0.596)  d is the orifice diameter (100mm), m  Po is the pressure drop across the orifice  ρ is the density of air, m3  Compressor total pressure  Ptf = + (p2-p1)  V1=Q/A1  V2=Q/A2  A1 and A2 are calculated based on the inlet and outlet radii of 50mm and 37.5mm respectively.  Input power of the motor    Useful ( or output) Air power:  Pair=Q x ΔPtf  Overall efficiency (including transmission):      Surge Line  Choke Line  Figure 10.3 Centrifugal Compressor Map. | | | 1. **Nomenclature**  |  | | --- | | Hs= static head  Po = outet pressure  Pi= inlet pressure  ρ= density of air  g= acceleration due to gravity  Ai= inlet area  di= inlet diameter  Ao= outlet area  do= outlet diameter  Hv= dynamic head  Vo= velocity at outlet  Vi= velocity at inlet | | | 1. **Reference**  |  | | --- | | 1. Fluid Mechanics and Thermodynamics of Turbomachinery-by Dixon and Hall 6th edition | | |