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SELECTION OF MATERIAL USED FOR DIFFERENT COMPONENTS OF CENTRIFUGAL COMPRESSOR

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Abstract: Design of Turbo machinery is complex and efficiency is directly related to material performance, material selection is of prime importance. The selection of materials for rotating and stationary components of centrifugal compressors requires consideration of a number of factors. This paper is focused on the properties of the material tensile properties, modulus of elasticity, thermal expansion, fracture toughness, damping, fatigue strength, thermal conductivity, specific heat, harden ability, weld ability, corrosion resistance and thermal stability. This paper presents a critical review of the existing literature of centrifugal compressor materials. This paper will focus on the Causes of Failure of Compressor and its Components and the Selection of Material used for different components of Compressors.
Keywords: Gas Turbine, Compressor, Turbine, Blade, Coatings

I. INTRODUCTION

This paper will focus on the Causes of Failure of Compressor and its Components and the Selection of Material used for different components of Compressors. This section will provide an idea on the type of compressor technologies available in today's market. Compressors are one of the central parts of conventional refrigeration systems, along with the condenser, the evaporator and the thermal expansion valve and also a part of Gas turbine. Compressor technology has evolved over the last century, and there are presently several different types compressors available. Generally, compressors can be split into two broad categories, positive displacement and dynamic compressors. Positive displacement compressors achieve compression through the reduction of the compression chamber volume. Low pressure refrigerant vapour enters the compression chamber through the suction port of the positive displacement compressor, and mechanical work decreases the volume of the chamber causing the vapour pressure to rise. This high pressure refrigerant is then allowed to escape the chamber through the discharge port. Positive displacement compressors are typically driven by an electric motor. Reciprocating compressors, orbital compressors, and rotary compressors are the main classes of positive displacement compressors. Orbital compressors include scroll and trochoidal compressors, while rolling piston, rotary vane, single screw and twin screw compressors are types of rotary compressors. In addition to positive displacement compressors there are also dynamic compressors. Dynamic compressors achieve compression of refrigerant vapour through kinetic energy transfer to the vapour. This energy is then converted into a pressure rise. Centrifugal compressors are dynamic compressors because they have a mechanical element which is rotating at a high speed. Angular momentum is then exchanged from this element to the steadily flowing refrigerant liquid. This thesis will focus on reciprocating and centrifugal compressors, which are discussed below in more detail.

II. CENTRIFUGAL COMPRESSOR

Centrifugal compressors, also known as turbo-compressors belong to the roto- dynamic type of compressors. In these compressors the required pressure rise takes place due to the continuous conversion of angular momentum imparted to the refrigerant vapour by a high-speed impeller into static pressure. Unlike reciprocating compressors, centrifugal compressors are steady-flow devices hence they are subjected to less vibration and noise. Figure2.1 shows the working principle of a centrifugal compressor. As shown in the figure, low-pressure refrigerant enters the compressor through the eye of the impeller (1). The impeller (2) consists of a number of blades, which form flow passages (3) for refrigerant. From the eye, the refrigerant enters the flow passages formed by the impeller blades, which rotate at very high speed. As the refrigerant flows through the blade passages towards the tip of the impeller, it gains momentum and its static pressure also increases. From the tip of the impeller, the refrigerant flows into a stationary diffuser (4). In the diffuser, the refrigerant is decele rated and as a result the dynamic pressure drop is converted into static pressure rise, thus increasing the static pressure further. The vapour from the diffuser enters the volute casing (5) where further conversion of velocity into static pressure takes place due to the divergent shape of the volute. Finally, the pressurized refrigerant leaves the compressor from the volute casing (6).

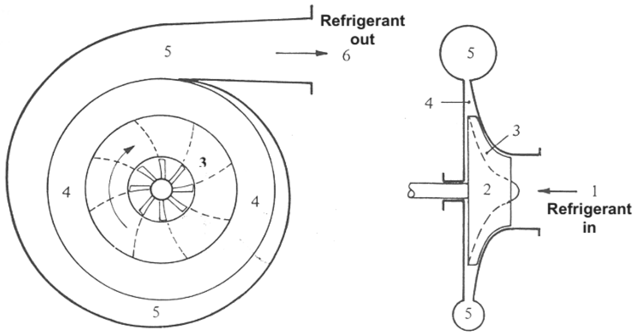

Figure2.1 Centrifugal Compressor

1: Refrigerant inlet (eye); 2: Impeller; 3: Refrigerant passages 4: Vane less diffuser; 5: Volute casing; 6: Refrigerant discharge

III. COMPONENTS OF CENTRIFUGAL COMPRESSOR

3.1 Inlet

The inlet to a centrifugal compressor is typically a simple pipe. It may include features such as a valve, stationary vanes/airfoils (used to help swirl the flow) and both pressure and temperature instrumentation. All of these additional devices have important uses in the control of the centrifugal compressor.

3.2 Impeller

The key component that makes a compressor centrifugal is the centrifugal impeller, which contains a rotating set of vanes (or blades) that gradually raises the energy of the working gas. This is identical to an axial compressor with the exception that the gases can reach higher velocities and energy levels through the impeller's increasing radius. In many modern high-efficiency centrifugal compressors the gas exiting the impeller is traveling near the speed of sound. Euler's pump and turbine equation plays an important role in understanding impeller performance.

3.3 Diffuser

The next key component to the simple centrifugal compressor is the diffuser. Downstream of the impeller in the flow path, it is the diffuser's responsibility to convert the kinetic energy (high velocity) of the gas into pressure by gradually slowing (diffusing) the gas velocity. Diffusers can be vaneless, vaned or an alternating combination. High efficiency vaned diffusers are also designed over a wide range of solidities from less than 1 to over 4. Hybrid versions of vaned diffusers include: wedge, channel, and pipe diffusers. There are turbocharger applications that benefit by incorporating no diffuser. Bernoulli's fluid dynamic principle plays an important role in understanding diffuser performance.

3.4 Collector

The collector of a centrifugal compressor can take many shapes and forms. When the diffuser discharges into a large empty chamber, the collector may be termed a Plenum. When the diffuser discharges into a device that looks somewhat like a snail shell, bull's horn or a French horn, the collector is likely to be termed a volute or scroll. As the name implies, a collector's purpose is to gather the flow from the diffuser discharge annulus and deliver this flow to a downstream pipe. Either the collector or the pipe may also contain valves and instrumentation to control the compressor.

3.5 Casing

The case (casing or housing) is the pressure-containing component of the compressor. The case houses the stationary internal components and the compressor rotor. Bearings are attached to the case to provide both radial and axial support of the rotor. The case also contains nozzles with inlet and discharge flange connections to introduce flow into and extract flow from the compressor. The flange connections must be properly sized to limit the gas velocity as necessary. The case is manufactured in one of two basic types:

- Horizontally
- Vertically split

Horizontally (axially) split case

A horizontally split case is split parallel to the axis of the rotor. The upper half of the case is bolted and doweled to the lower half. Access to the internals of the compressor for inspection and maintenance is facilitated with this case design (especially when the process piping connections are located on the bottom half of the case). The horizontally split design is inherently pressure-limited to prevent gas leakage at the case split joint.

Vertically (radially) split case

This case is split perpendicular to the axis of the rotor. Heads (end covers) are installed at both ends for pressure containment. The vertically split case configuration is capable of handling higher pressures than the horizontally split type. The rotor and stationary internals are assembled as a cylindrical inner bundle that is inserted axially through one end of the case. Inspection and maintenance of a radially split centrifugal compressor require that the inner bundle be removed for disassembly. Removal of the inner bundle requires that sufficient space be provided in the layout of the compressor installation.

IV. MATERIAL USED IN DIFFERENT COMPONENTS OF CENTRIFUGAL COMPRESSOR

In today's market place the selection of materials for the various components for Centrifugal compressors is very competitive and an important factor in the overall cost and delivery of the product. The selection of materials for Inlet, Impeller, Diffuser, Collector and Casing as well as other components requires consideration of a number of factors.

- Tensile properties
- Modulus of elasticity
- Thermal expansion
- Fracture toughness
- Damping
- Fatigue strength
- Thermal conductivity
- Specific heat
- Corrosion resistance
- Thermal stability

The common Centrifugal Compressor impeller Materials are AISI 304, Al 6A14V, Al 2025T6, Al 7050T73 and Ti unalloyed and their Mechanical Properties are given in Table4.1.

IMPELLER MATERIALS

There have been few changes in the most commonly used impeller materials in a number of years. Chromium – molybdenum alloy steels in the AI S I 4lxx series continue to be used in the smaller sizes and the nickel-chromium - molybdenum A I S I 43xx series in the larger sizes. The exact carbon contents in these grades vary a little among different manufacturers, but the principles remain the same. As may be seen from the chemical compositions in Table, the 43xx series is more highly alloyed than the 4b:x series. The significance of this is that the higher alloy

Content imparts more hardenability to the 43xx compositions. In the sizes where the 4lxx series has sufficient hardenability, there is no advantage to using the more highly alloyed material. In the larger sizes, 43xx is a better choice. The term hardenability is not a measure of the maximum hardnes s that can be developed on quenching. Rather, it is a measure of the maximum section size of the material that will develop the required properties.

Table4.1 Mechanical Properties of Impeller Materials

Material	Tensile Strength (ksi)	Yield Strength (ksi)	Elongation (pet)	Reduction of area (pet)	Brinell Hardness
AISI 304	70	30	40	50	200
Al 6A14V	40	33	3	-	100
Al 2025T6	50	33	3	-	125
Al 7050T73	74	65	5	-	142
Ti unalloyed	65	40	17	30	200

Shaft Materials

In recent years, there has been much concern and discussion concerning shafts. Little of it, however, has had to do with the basic materials. Most shafts continue to be made from alloy Steels such as AI S I 4130, 4140, 4330, 4340 and related modifications. A comprehensive list of shaft materials in Table 4 includes some which are seldom, if ever, used for compressors hafts. In addition to the alloy steels already mentioned, Type 410, Type 304, and 17-4PH have been used occasionally. The other grades are or have been used for turbine rotors, and will be of interest in the discussion of wire wool failures. The mechanical properties of the most frequently used shaft materials are listed in Table. These tables are not intended to include all possible shaft materials, but to give an understanding of the type s of alloy steels, and the accompanying properties of shafts that have a history of satisfactory service.

Table4.2 Mechanical Properties Most Frequently Used Shaft Materials

Material	Tensile Strength (ksi)	Yield Strength (ksi)	Elongation (pet)	Reduction of area (pet)	Brinell Hardness
AISI 4140	100	75	16	45	207-320
AISI 4340	115	90	16	45	235-320
Mod.4340	125	115	15	40	245-340

V. COMPRESSOR PROBLEMS

Problems with compressors generally fall into one of three broad categories are Loss of capacity, Noise and vibration and Failure to run. The following Problems related to vibration and failures in compressor include:

- Dynamic excitation (high cycle fatigue).
- Compressor surge.
- Rotating stall and flutter.
- Blade rubs.
- Foreign and domestic object damage (FOD/DOD).
- Migration of blades.
- Corrosion.
- Erosion.

Predominant failure mechanisms and commonly affected components of Gas turbine engine are:

• Low cycle fatigue-compressor and turbine blades and disks.
• High cycle fatigue-compressor and turbine blades, disks, compressor stator vanes.
• Thermal fatigue-nozzles, combustor components.
• Environmental attack hot section blades and stators, transition pieces, and combustors.
• Creep damage-hot section nozzles and blades.
• Erosion and wear.
• Impact overload damage (due to foreign object damage (FOD), domestic object damage (DOD) or clash/clang of compressor blades due to surge).

Table 5.1 Failure modes and causes of different parts of a Centrifugal Compressor

Component	Failure Mode	Cause
Impeller (Contents set of Rotor Blade and Stators)	HCF, Erosion, corrosion, FOD, fretting, tensile failure.	Vibration. Flutter, airflow distortion, surge, Stall dust in air.
Disc	Fatigue- creep, wear, rubbing	Centrifugal loads temperature effect
Compressor tie bolts	Mechanical fatigue, wear, fretting and rubbing.	Start up, cycling, vibration

VI. CONCLUSION

This paper provided the selection of a material type depends on how the part will be made, the strength required, and the operational environment. There are other considerations made in designing each specific part to help select between several very similar materials and alloys. This paper documents a number of different materials that can be used for compressor and gas turbine applications.

REFERENCE

[1] Callister Jr., William D., "Materials Science and Engineering An Introduction", New York: John Wiley & Sons Inc. 2007.
[2] Centrifugal Compressors, Version 1, ME, IIT Kharagpur.
[3] Cyrus B. Meher-Homji, "Gas turbine blade failures-causes, avoidance, and troubleshooting", Engineering Specialist Bechtel Corporation Houston, Texas and George Gabriles Consultant G&B Consultants Lake Jackson, Texas, pp.130-133.
[4] Joseph A. Cameron, "materials for centrifugal compressors a progress report", Metallurgical Engineer Greensburg, Pennsylvania.
[5] Joseph A. Cameron,"materials for reciprocating compressors-A progress report", Metallurgical Engineer Greensburg, Pennsylvania.
[6] Refrigeration System Components, Compressors, Version 1, ME, IIT Kharagpur.

