

High Temperature Fans

Introduction

When fans are exposed to elevated temperatures, many aspects of the fan design must be reviewed to make sure the fan will withstand the extreme temperatures and that the fan is appropriately designed for the application. The fan engineer must understand the limitations of materials and various failure mechanisms, such as high stress, stress to rupture, and creep. Sometimes, it is necessary to consider high cycle fatigue, low cycle fatigue in cyclical operation with speed changes and numerous start-stop cycles. If rapid temperature changes are encountered, transient analysis may be required due to thermal stresses.

Depending on the exposed temperature levels, the following are to be considered:

- Materials of construction for the impeller, shaft and hub
- Impeller to hub attachment
- Materials of construction for the housing including insulation
- Bearings and lubrication
- Shaft seals
- Shaft cooling (air-cooled, water-cooled, etc.)

Limits on the operating temperature for standard fans are defined by the arrangement of the fan. For example, the maximum temperature for a standard fan that does not have a bearing in the airstream (Arrangements 1, 8, 9 or 10) can run up to 300°F. For standard fans that have a bearing in the airstream (Arrangements 3 or 7), the maximum operating temperature is limited to the maximum temperature that the bearing can handle, which is typically about 130°F.

Impeller Design

Carbon steel, low alloy high strength steels and chrome moly steels are satisfactory for a temperature range of 900° to 1000°F, depending on stress levels. Heat resistant alloys such as stainless steels (304, 316, 321, 330), Incolloy 800HT, 230, Inconel (600, 625, 617), Multimet, Haynes 25, etc. should be used for higher temperatures up to 1800°F. Again, the material chosen also depends on the stress levels and the material properties at elevated temperatures.

Table 1.

MATERIAL NAME	YIELD (KSI) AT TEMPERATURE (°F)																	
	70	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
MILD STEEL	35.00	34.30	33.75	33.27	32.59	31.92	31.19	30.27	29.37	28.35	26.43	22.40	17.15	12.60				
CORTEN STEEL	49.98	48.98	48.24	47.50	46.53	45.81	44.53	43.28	41.97	40.82	39.85	38.73	37.57	35.00				
304 STAINLESS	30.93	27.91	26.82	25.89	54.75	23.82	22.74	21.84	21.02	20.22	19.37	18.65	18.04	17.59	17.05	16.62	16.09	15.25
DUPLEX 2205 STAINLESS	75.00	50.00	47.20	46.10	45.90	45.00	43.90	42.80	41.20	40.00								
ALUMINUM 5052	28.00	28.00	26.20	24.40														
ALUMINUM 6061-T6	35.00	33.65	32.34	27.41														

Temperature derates lower the maximum speed of an impeller to account for the lower material strength at elevated temperatures. See Table 1 below for some material yield strengths at different temperatures.

The impeller must sustain the highest stress of all the fan components. It is very important that the material used on the impeller is strong enough to handle the stress at high temperatures. At higher temperatures, material creep must be considered.

Shaft, Bearings and Bearing Lubrication

Bearings usually require high temperature lubricants and sometimes circulating oil or static oil in a monoblock. Bearings can be kept cool in high temperature applications by using a shaft cooler (see Figure 1 on page 2) and a shaft seal. For higher temperature fans, water cooling can be used to cool the shaft. In this case, the fan should be belt driven in order to install a rotating union to circulate the water over the shaft.

Bearings should be kept out of a high temperature airstream and should never run in air temperatures hotter than 130°F. The inboard bearing, which is the bearing nearest the fan housing, should be moved away from the fan housing to create some space for the heat to dissipate. The space created between the inboard bearing and the fan housing allows for the use of a shaft cooler (see Figure 1 below) and shaft seal. Bearing temperatures should be monitored and should not be allowed to exceed 200°F at speeds higher than 2500 RPM and 220°F at speeds below 2500 RPM.

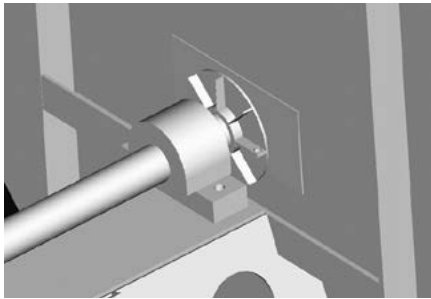
Bearings should be selected to allow for free movement of the shaft lengthwise due to temperature changes. One bearing should be fixed, serving as an anchor bearing to locate the shaft lengthwise. The bearing closest to the drive end is normally fixed. All other bearings should be expansion bearings to permit the shaft to move lengthwise. The thermal growth of the shaft may limit the bearing used.

Shaft materials are typically carbon steels, alloy steels, stainless steel (304, 316, 330) and sometimes Inconel, depending on the application. The thermal conductivity of stainless steel is lower than mild steel, and therefore is a better material choice at extreme temperatures.

Shaft Cooler (Heat Slinger, Heat Flinger, Cooling Wheel)

A shaft cooler is a small fan that clamps on the shaft between the fan housing and the inboard bearing (see Figure 1). The shaft cooler draws cool air over the shaft and bearings as the shaft rotates to dissipate the heat. A shaft cooler is recommended for all applications over 300°F. Generally, the pedestal must be modified to allow room for the shaft cooler. This will increase the distance between the inboard bearing and the impeller. This dimension, referred to as the overhang dimension, is critical in determining the safe speed of the shaft. As the overhang dimension is increased, the shaft safe speed becomes lower. During maintenance repairs, it is very important that the overhang dimension is never increased.

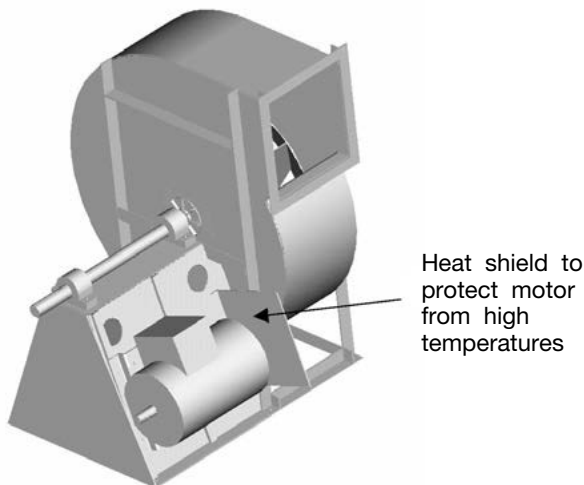
Figure 1. Shaft Cooler



Modifications to Motor/Bearing Pedestals

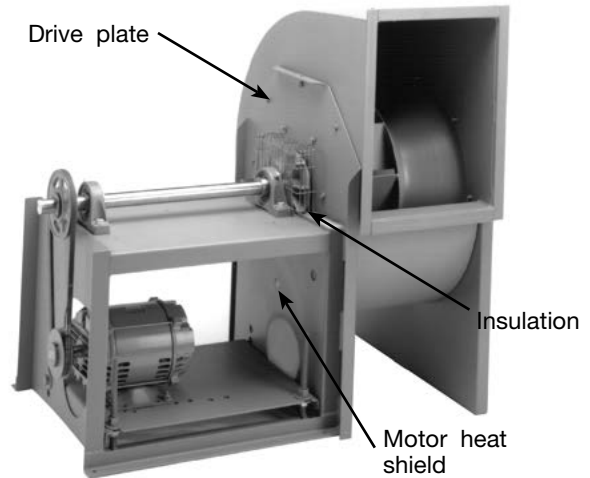
For high temperature applications, special modifications may need to be made to the pedestal to allow space between the bearing or motor and the hot fan housing. For Arrangement 9 fans, the motor should have some type of heat shield as shown below in Figure 2. The heat shield acts to deflect the radiant heat away from the motor.

Figure 2. Motor Heat Shield on Arrangement 9



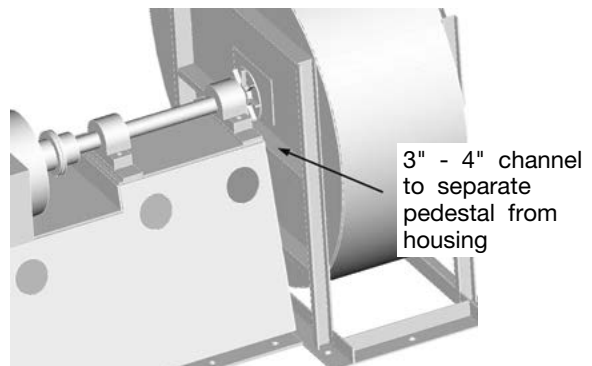
On Arrangement 10 fans, a heat shield is also used but is slightly different from the one used on an Arrangement 9 fan. Because an Arrangement 10 fan has the motor under the pedestal, the radiant heat cannot just be deflected. Therefore, it is recommended to add some insulation between the fan housing and the pedestal. See Figure 3 below.

Figure 3. Modified Arrangement 10 - Insulation Between Fan and Pedestal



When the temperature exceeds 800°F, it is necessary to separate the pedestal from the fan housing. By doing this, the amount of heat conducted through the pedestal and to the bearings and motor is greatly reduced. The pedestal is separated from the fan by welding either a channel or angle supports between the two as shown in Figure 4.

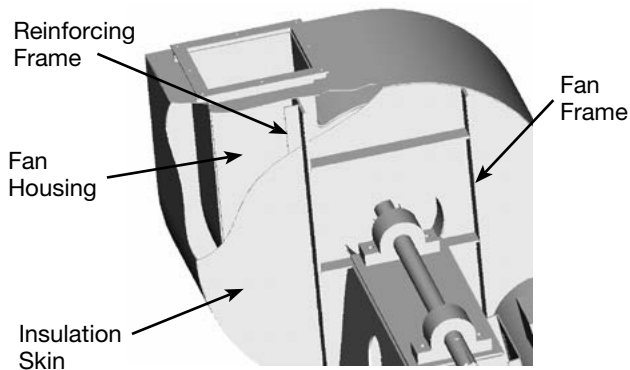
Figure 4. Separated Pedestal Design



Housing Design

For housing material, carbon steels are satisfactory for temperatures up to 800°F and Corten is often used for temperatures up to 1000°F. For higher temperatures, stainless steels and Inconel may be required. A customer may want to keep the heat of the airstream from heating up the fan housing and radiating out to the surrounding area. Insulating the fan accomplishes this. There are a few ways to insulate a fan, but the main idea is to create a second fan housing offset from the main fan housing and then fill the gap between the two with insulation. It is common to have 2" - 6" of insulation depending on the temperature of the airstream and the need for the outer skin to be cool. See Figure 5 below. For fans that require an access door and also have an insulated housing, the access door is raised from the fan housing to the outer insulation skin by building a box between the two housings.

Figure 5. Cut-Away of Insulation Skin



Axial Fans

Up to this point, the discussion has centered on centrifugal fans. It should be mentioned that there are a few modifications that are specific to axial fans. Standard axial fans are good to 200°F. By moving the bearing housing upstream of the impeller, opening the bearing housing to the impeller, and by adding a cooling wheel to the shaft to pull cool air over the shaft and bearings, the maximum operating temperature goes up to 300°F. With a change of impeller material to aluminum A240, some axial fans can be made to run in temperatures as high as 600°F.

Conclusion

When a fan is installed in a high temperature application, it is important for the engineer to properly design the components of the fan. This includes, but is not limited to, the impeller, shaft, bearings and housing. The impeller material should be selected to provide adequate strength at the elevated temperature. The shaft and bearings may require a cooling system or other means to keep them from overheating. The bearings should have proper lubrication that can handle the higher operating temperatures. Sometimes an insulated housing should be manufactured to keep the heat from radiating out to the surroundings of the fan. High temperature fans, if designed properly, can provide years of dependable service.



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