REFURBISHMENT OF AXIAL FANS FOR TUNNEL VENTILATION SYSTEMS

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SUMMARY:

During recent years Zitron Nederland has refurbished numerous axial and jet fans for tunnel ventilation systems. Examples are the Arlbergtunnel, the Perjentunnel, the Katschbergtunnel and the Bosrucktunnel in Austria and the Kerenzertunnel, the Fäsenstaubtunnel, the Belchentunnel and the Seelisbergtunnel in Switzerland. In this paper Zitron Nederland will share the experiences gained during these refurbishment projects and present some of the lessons learned.

Following topics will be discussed in the paper:
- Scope of refurbishment
- Overhaul of impeller and blades, renewal of blades and bearings
- Overhaul of major components (drive motors, fan isolation dampers, ducting etc.) and surface treatments
- Renewal and improvement of fan sensors and controls, communication with control system
- Re-commissioning of fans and ventilation systems
- Logistical aspects of refurbishment projects “under traffic”

1. GENERAL

Electrical and mechanical equipment for road and rail tunnels are commonly designed for life cycles of 20 to 40 years.

Fans for ventilation systems, jet fans for longitudinal ventilation and axial fans for fresh air supply and extraction of polluted air and smoke are typically designed for a life time of 25 (jet fans) to 40 years (axial fans).

This design life time is considerably shorter than the design life time of the tunnel itself which will be at least 100 years. Therefor refurbishment of electro-mechanical components such as jet and axial fans will be a necessity. Also upgrading of tunnel ventilations systems with the goal to comply with EU-regulations creates an opportunity for refurbishment of existing equipment.

2. JET FANS

Jet fans are designed for a life time of approx. 25 years. In practice jet fans often need to be refurbished after approx. 15 years of operation. The main cause of failure is the drive motor, more specifically the motor bearings.

Specifications quite often call for motor bearings which are “greased for life”. In practice drive motor suppliers guarantee bearings for a L10 lifetime of max. 40.000 hours. This number means that 90% of the bearings should reach min. 40.000 hours of operation, 10% of the bearings may fail.

Jet fans and its drive motors need to be certified for 250 or 400 ºC for 60, 90 or 120 minutes. To comply with this requirement, motor suppliers select a high temperature (high viscosity) grease which has acceptable lubrication properties at high temperatures at the cost of the lubrication properties at ambient temperature.

Suppliers of lubricants have recommendations for shelf and service life of their greases. The values vary but are far from the 25 years which is theoretically required for “life time greased bearings”.

It is recommended to apply grease nipples on motor bearings to enable re-lubrication.

Smaller jet fans should have a greasing tube with a nipple on the fan casing for accessibility.

Drive motor housings are made from cast iron or aluminium with a surface protection. The experience learns that, also when a surface treatment to suit the highest corrosion category (C5) is applied, after 10 to 15 years severe corrosion to the motor housings may occur.

For a “mid-life refurbishment” of jet fans customers may decide to renew the drive motor in its whole or to dismount the motor, replace the motor bearings, check winding insulation and renew the surface treatment of the motor housing. Jet fans should be dismounted from the tunnel and transported to a work shop for this.

For an overhaul or renewal of the drive motor the jet fan impellers must also be removed. This enables cleaning and dye penetrant inspection of the blades. The impeller hubs will have to be cleaned and possibly be re-coated. Removal of jet fan impellers from the motor shaft after a number of years of operation often proves to be a challenge where hydraulic tools are required. Blades often show damages due to objects passing through the fan. After re-assembly the impeller must be re-balanced.

Renewal of motors can cause problems as current regulations dictate high efficiency class motors which can affect frame size and shaft dimensions. A replacement

with a dimensionally identical motor may then not be possible.

Nowadays jet fan casings and jet fan silencers for road tunnel ventilation are largely fabricated from stainless steel. For rail tunnels also galvanized and painted steel is accepted.

When jet fan silencers are fabricated using rivets and/or spot welding, damage may occur caused by shear stresses on the joints induced by vibrations. Silencer parts should be joined by continuously welding. Spot welding and riveting should be avoided.

Due to the need for tunnel closures, the use of dedicated vehicles/hoisting equipment and the man-hours involved refurbishment of jet fans is, compared to the initial investment, relatively expensive. An additional initial investment to extend operating life will quickly be worthwhile.

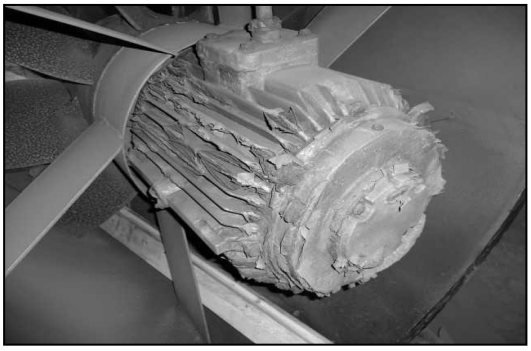

Figure 1: Corroded jet fan motor

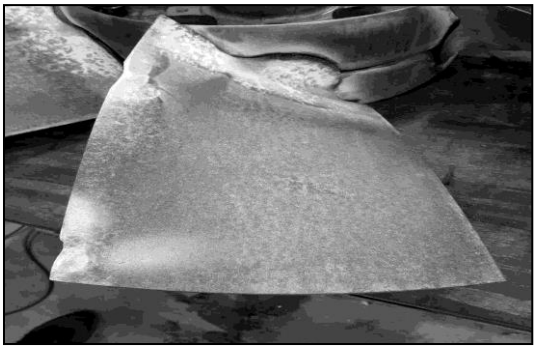

Figure 2: Damaged jet fan rotor

3. AXIAL FANS

Depending on actual operating conditions axial fans for fresh air supply and extraction of polluted air will need a major overhaul after approx. 20 years. Fan system components to consider are:

- Drive motor
- Impeller
- Instrumentation and sensors
- Static parts such as fan casings, diffusors, inlet bells/grids, ducting and guide vanes
- Flexible connections
- Fan isolation damper

To enable overhaul of impeller and drive motor these components should be dismounted and be transported to a dedicated work shop. Ideally hoisting equipment and installation hatches are foreseen to enable taking out the complete fan unit or at least the motor/impeller combination. In case no hoisting equipment is foreseen temporary hoisting equipment will have to be installed.

3.1 Drive motor

An overhaul of a drive motor consists typically of following activities:

- Replacement of the bearings
- Replacement of bearing temperature sensors (winding temperature sensors remain)
- Replacement of encoder
- Check of stator winding insulation (when not adequate re-winding is required)
- Check of drive shaft and seats
- Re-balancing of rotor
- Cleaning, repair or renewal of surface treatment

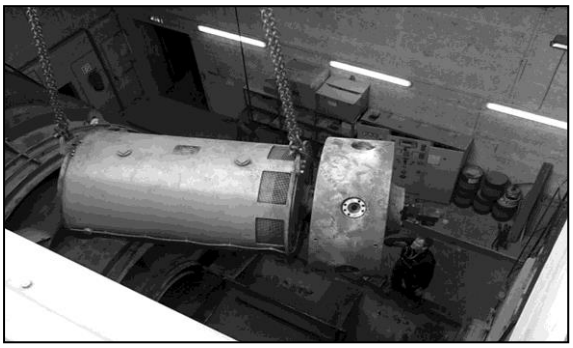

Figure 3: Disassembly of motor/impeller

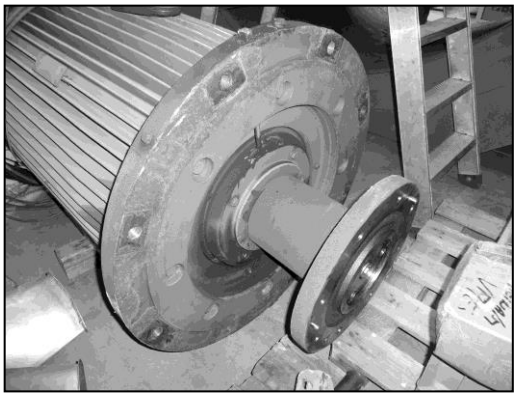

Figure 4: Disassembled motor

3.3 Impeller

The impeller must be removed from the drive shaft. Often this will require special hydraulic removal tools.

Overhaul of an impeller mainly comprises of:

- Dismounting blade adjustment mechanism, blades, blade suspension and blade bearings
- Cleaning and dye penetrant or X-ray checking of blades, blade spindles and hub

- Renewal of bearings, seals, (blade) bolts and fasteners
- Re-apply surface treatment of the hub
- Balancing of the assembled impeller

Special attention and often special tooling is required to remove the impeller from the drive shaft. Fan manufacturers often use modified or custom-made bearings. A simple 1:1 replacement of blade bearings can result in considerable damage.

Blades may show small damages due to foreign objects passing through the fan. Depending on the severity of the damages and the results of the non-destructive tests renewal of the blades may be required.

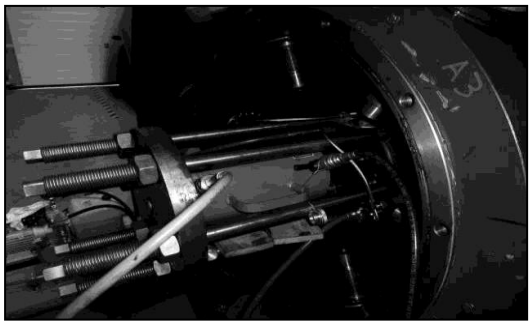

Figure 5: Disassembly impeller

Figure 6: Disassembly blade

Special attention needs to be given to the blade suspension bolts, often made of high tensile strength material. After dismounting these have to be renewed.

Blades of impellers with blades adjustable at standstill can be stuck due to deposits or corrosion and prove impossible to remove. In that case machining will be required and blades will have to be renewed.

Figure 7: Mechanical removal blade

Figure 8: Parts blade suspension

Nowadays with material analysis and 3D scanning techniques it is possible to make a good quality copy of existing blades. Nevertheless, it is recommended to check blade loads in relation to the high temperature requirement in case of emergency exhaust fans.

3.4 Static parts

Static parts such as fan casings, diffusors, inlet bells/grids, ducting and guide vanes, usually made from carbon steel with a multilayer surface treatment will show signs of corrosion in various degrees after 10 to 15 years of operation. For a durable refurbishment, the corroded parts should be cleaned thoroughly by pellet blasting.

Ideally the static parts should be dismounted and transported to a work shop where blasting and application of new layers of surface treatment can be done in a controlled environment. Pellet blasting in the fan room

Figure 9: Fan casing after treatment

causes a lot of dust. Used pellets contaminated with paint and oxidized particles are often considered as chemical waste with special disposal regulations.

Application of layers of paint in fan rooms under non-optimal conditions require special attention as the layers of paint may show delamination.

Figure 10: Delamination after treatment

Dry ice cleaning with CO2 pellets is a good alternative for cleaning and removal of deposits. Only the deposits remain after cleaning and need to be disposed. Dry ice cleaning is inadequate to remove the corrosion and subsequent application of new layers of paint.

3.5 Fan isolation damper

During a fan refurbishment also the fan isolation damper should be cleaned, the bearings of the damper blades need to be renewed. The actuator will have to be dismounted and sent to the original supplier for renewal of seals and checking the switches.

3.6 Hydraulic unit

Refurbishment of the hydraulic unit powering the blade adjustment mechanism consists of following activities:

- Check and measurement of the oil pumps
- Remove oil and clean the system
- Check of temperature, pressure and level sensors, replacement if required.
- Renew seals
- Renew tubes
- Fill with new oil
- Renew surface treatment

3.7 Fan instrumentation

For a safe and accurate operation large tunnel ventilation fans should be equipped with following instrumentation:

- Speed and sense of rotation
- Measurement of temperature of motor windings and motor bearings
- Volume measurement
- Fan pressure measurement
- Stall monitoring system
- Vibration measurement in X- and Y-axis
- Blade angle measurement system (in case of a fan with blade adjustable during operation)

Knowing the speed and the sense of rotation of the fan is essential for a safe start of the fan. Volume and pressure measurement is required for an accurate control of the ventilation system. Temperature and vibration measurement enables condition monitoring of fan and drive motor.

When the fan is already equipped with the above instrumentation, the equipment should be thoroughly checked if not renewed completely. Signals must be validated during re-commissioning.

In case some of the instrumentation is not present, we recommend to install this additionally.

When the ventilation system control system is also renewed during a refurbishment of the tunnel equipment, careful consideration must be given to the moment of switching from the existing to the new control system. Refurbished fans with new instrumentation often have to be re-commissioned before the next fan to be refurbished can be taken out of operation. New instrumentation may not be compatible with the existing control system.

4 Logistical aspects

A full closure of an existing tunnel for a longer period of time is usually not acceptable to the public. In winter periods alternative routes may not be available. This means that as a rule, fan refurbishment has to be carried out during temporary or even partly tunnel closures during the night.

In these cases, the actual available working time including the time frame for bringing equipment in and out of the tunnel is very limited. Working in parallel at multiple fans is usually not possible because of minimal ventilation requirements. This will extend lead times for refurbishment. Working in tunnels “under traffic” is inherently more dangerous than working in new built tunnels. Accurate registration of staff working in tunnels, enforcement of health and safety regulations and the use of well-instructed and experienced personnel is of the utmost importance for an accident free execution of the work.

References

Refurbishment of axial fans of tunnel ventilation systems, Frits van Vemden, Fred van Jaarsveld, Zitron Nederland, 9thInternational Conference ‘Tunnel Safety and Ventilation’ 2018, Graz