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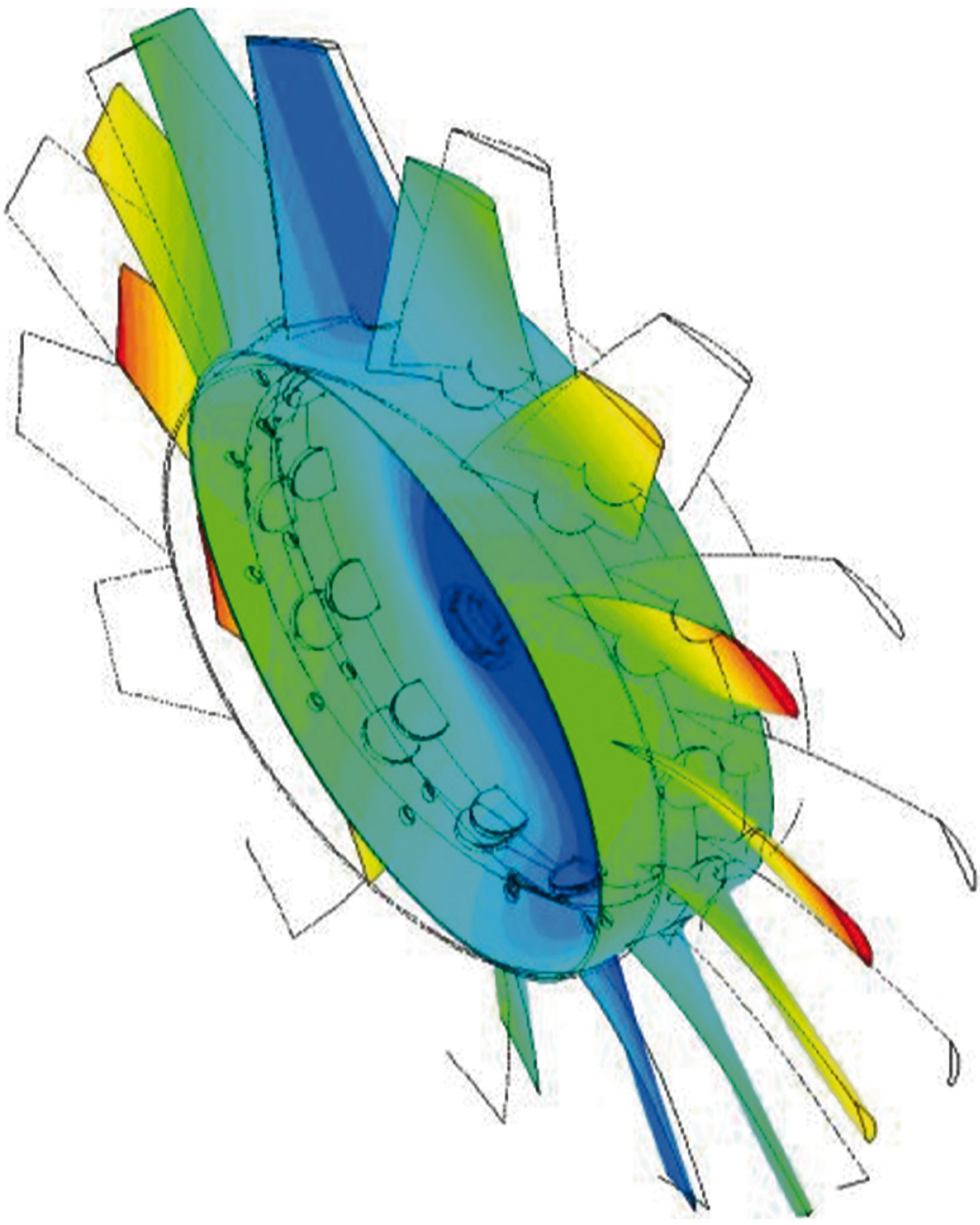

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Possible Effects of Dust and harmful Gases on Underground Fans

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Ventilating fans intended for use below ground have to be deemed 'fit for purpose' and they must be designed in a way that takes account of the proposed operating conditions. Practical experience with fan systems has pointed to the negative impact created by dust and gases, a factor that is often overlooked at the equipment planning and assessment stage.

Mining • Tunnelling • Ventilation • Mine fans • Sustainability • Efficiency

1 Introduction

Fans provide artificial air movement in mines. They are assigned to different applications. Main fans provide the total fresh air requirement for the mine workings (**Fig. 1**). Auxiliary fans provide pressure boosting or relief and support the overall ventilation system. Special fans are found around the primary haulage operation to bring fresh air to the workplaces and the working face. In doing so, they convey fresh and clean air. However, their use is often not so simple and the demands are much more than just a 'clean' and 'fresh' environment. Fans working in a negative-pressure operation ingest air that is already polluted. Special fans are located in places to dilute or transport emissions. Other fans are located in headings with blasting or mechanical excavation and are subjected to heavy mechanical loads. These operating conditions require suitably designed equipment.

A mining fan may look similar to an industrial fan, but the individual components of the mining fan have to withstand quite different conditions. Like an underground miner himself, it needs to be 'fit for mining'. This suitability for mining applications is achieved if the unit meets all the requirements for mechanical, electrical and chemical resistance. These requirements are not the same in every mine, so the equipment often needs to be adapted to suit.

This article uses examples taken from actual practice to present cases where mine fans were fit for purpose and where they were not.

Fig. 1: Main fan
Source of the figures: Korfmann Lufttechnik GmbH

2 Mechanical Load

There are many different mechanical loadings that a fan is subjected to. Of course, the internal mechanical forces acting on the impeller, shaft, bearings, motor and housing must be taken into account in the internal design. Some of the loads that are not always considered are those that occur due to other external parameters such as transport (**Fig. 2**) or assembly and which do not fall under the usual design criteria. These include sea and land transport in areas with an inadequate infrastructure. Due to the topographic conditions, considerably higher forces than with a load of only 1g (1g = acceleration due to gravity, this also being used as a measure for other rates of acceleration) can act on the overall structure. If these forces are not taken into account, parts can be pre-damaged and considerably shorten the service life in operation. Underground transport and the underground use itself often require partial dismantling of the components and non-standard placement of the slinging points in order to bring the equipment safely to its place of use with the tools available. Often, the handling and operation of special ventilation fans

Fig. 2: Transport damage

Fig. 3: Handling below ground

Fig. 4: Collapsed air screen

Fig. 5: Impeller damage

Fig. 6: The 'red-white' test

underground does not come close to the specifications in the operating instructions (**Figs. 3 and 4**). Mechanical forces that commonly occur in mining and act on the housing should not immediately lead to damage that makes operation impossible. Accordingly, a mining fan requires a stable housing and mechanical integrity. This also includes protection for the electrical connections and the motor as well as an engineering design that adequately considers the mechanical influences on the bearings, shaft, motor and impeller.

Larger particles of debris or loosened nuts from attachments that reach the rotating impeller can cause the instantaneous destruction of the entire impeller (**Fig. 5**). In some cases, however, the blades are only damaged but continue to be operated - whether through ignorance or intent. Sooner or later, this predamage leads to complete failure of the impeller and thus a write-off. To prevent this, maintenance is essential. Even simple visual inspections at an early stage can prevent far greater damage. Even small particles can cause preliminary damage to the impeller. The damage only becomes apparent after an indefinite period of alternating loads. Therefore, for large fans, regular inspections of the blade surfaces are recommended. Depending on the blade material and accessibility, this can also be done in-situ. An example of this is the so-called red-white test (dye penetration method) shown in **Fig. 6**. This is one way of testing for surface cracks. By applying a fine penetrant dye and then a developer medium hairline cracks can be detected and the component replaced at an early stage. Another non-destructive surface method is magnetic particle testing. For both methods, the material compatibility of the component with the test method/material is prerequisite.

Blade damage can not only be caused by objects, but also by extreme alternations of the blade loads during operation for which the impeller is not designed (**Figs. 7, 8 and 9**). In particular, this includes pressure peaks that counteract the pressure increase of the fan. Rapid pressure changes can be generated by fast-closing ventilation structures without pressure relief near main or auxiliary fans, dampers, doors or gates that are located directly in the air stream and are closed for whatever reason. There are many possible causes for this, e. g., automated but mis-programmed gates, unintentional operating errors by individuals, etc. Rapid pressure increases can cause fans to become unstable. In this unstable range, the fan is subjected to high aerodynamic loads and may even be run in an erratic 'pumping' mode. This mode of operation can completely destroy the fan in a very short time, as the forces that occur exceed the design parameters many times over.

Special fans used in blasting operations are often subjected to such loads by the shock waves from the blast, greatly reducing the life expectancy of such an impeller. Only rarely are any measures applied to protect the fan interior or cover the fan against shock waves. Particular reference should be made here to potential

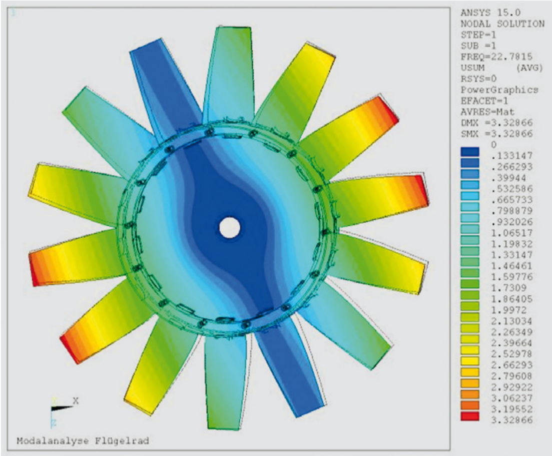

Fig. 7: 2D depiction of fan-blade deformation

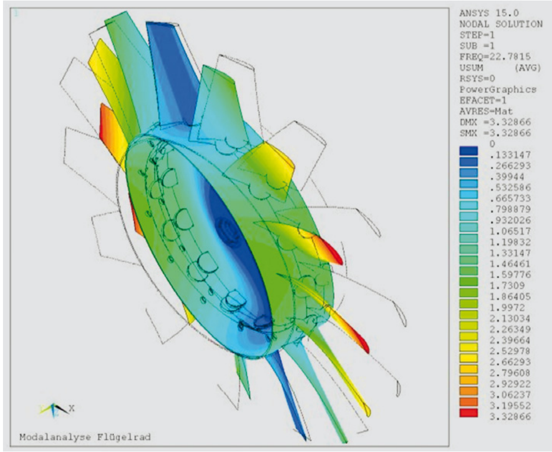

Fig. 8: 3D depiction of fan-blade deformation

preliminary damage to the impeller by small pieces of blasted rock.

3 Dust

3.1 Influences on the Mechanics

Heavily contaminated dirty air creates additional mechanical stress for a fan. This contributes to increased wear of the components (**Fig. 10**). This applies especially to the impeller. The air speed increases through the fan thereby turning the smallest particles into projectiles that attack the surface of the blade profile. In particular, the blade tips become the focus of attention, as they are fully engaged with the linear airflow on the suction side (**Fig. 11**). The consequence of a blade that is permanently loaded with particulates is that the tips no longer conform to the flow and the resulting poor flow paths. The internal forces increase, the efficiency decreases, the power increases and the operating values for volume flow and pressure increase are no longer achieved. The service life of the unit is considerably shortened and the replacement of wear components has to be carried out much earlier.

If the particulates in the air stream are solids such as dust, the wear rate of the blade tips increases immensely depending on the dust content. Especially dust con-

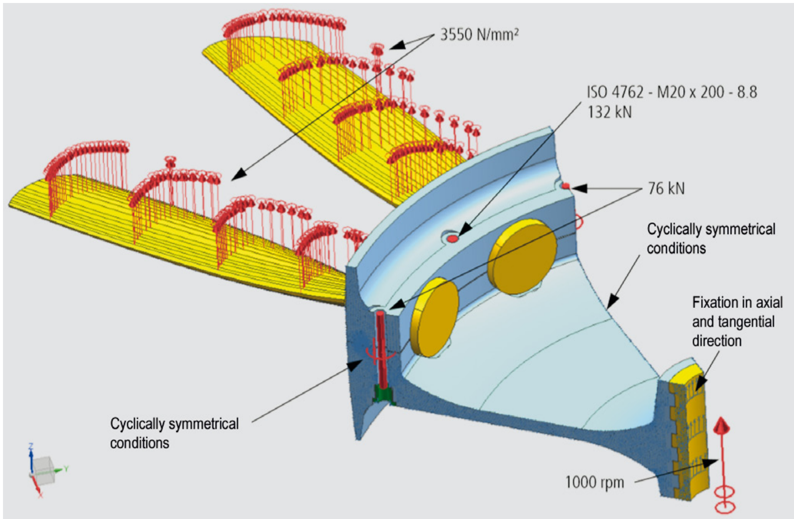

Fig. 9: Blade forces

taining quartz eats away at the blades, which are mostly made of aluminium alloys, within a very short time (**Fig. 12**).

But even fine, soft or moist dust can also cause more damage than just material wear. Soft dust, e. g., tends to settle between the cooling fins of the motors and clogs them. The particles tend to adhere in corners and edges, on screw heads and in places contaminated with lubri-

Fig. 10: Fan affected by airborne salt particles

Fig. 11: Severe abrasion at the blade tips

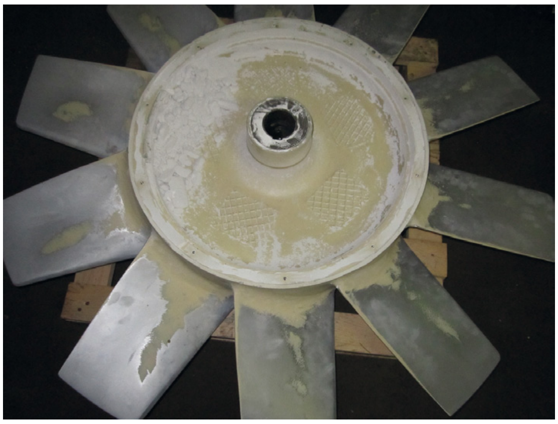

Fig. 12: Dust deposits

Fig. 13: Anhydrite mine – fan position

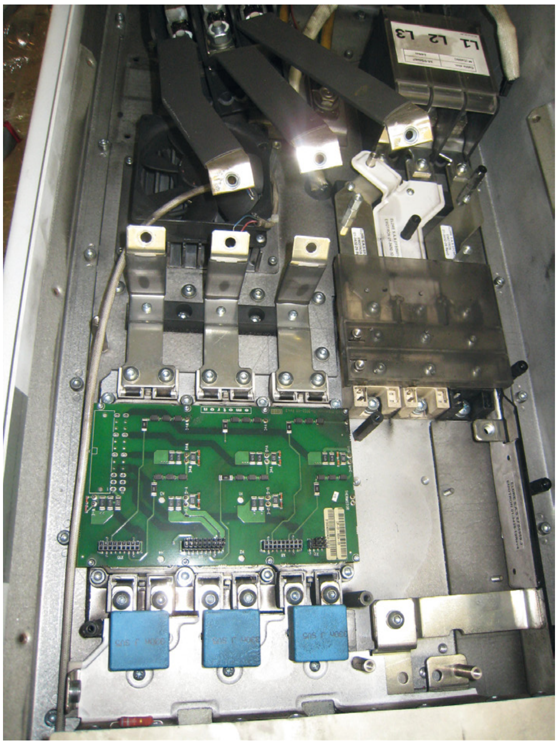

Fig. 14: Anhydrite mine – fan controller

cants or moisture. For a uniformly designed rotating body such as the impeller, this is not critical in the first instance because the movement of the component and the even distribution of the particles over the cross-section mean that they are also deposited uniformly. Initially, the balance of the rotation is not disturbed. However, as soon as the particles settle unevenly or a piece of accumulated particle cake detaches, the imbalance of the impeller suddenly increases. Increased vibrations are the result, which lead to damage when critical values are reached. If this is to be prevented, the intake air should not be contaminated with dust particles in the first place. This can be achieved by using pre-separators and de-dusting units. In any event, in most countries, there is no alternative to the use of such units because, apart from the advantages for the fans, they are especially important to ensure compliance with the applicable dust exposure limits and thus to protect the miners' health. Where partial contamination of the air flow is unavoidable, the fan must be checked by regular visual inspections appropriate to its operation and cleaned if necessary.

With the help of modern sensors, fans can also be monitored automatically. An imbalance can be detected by means of vibration monitoring. Unstable operation in terms of fluid dynamics can be detected by means of stall point monitoring, e. g., by means of a Petermann probe. However, even these sensors can show errors depending on the environmental conditions and require further technology and fine-tuning. Each operator must decide for himself which type of monitoring is best-suited to his operation.

3.2 Influences on the Electrics and other Components

Often dusts and other solid particulates are not only a mechanical problem. While some highly crystalline fine particles put considerable strain on seals and lubricants, some chemical compositions are more problematic for other components. In particular, electrical components can become contaminated and exhibit various fault patterns. Some dusts are so fine that they cannot be completely excluded from electrical enclosures, even with higher protection classes and intensive maintenance efforts. The fan control panel from an anhydrite mine shows such case (**Figs. 13 and 14**). Here, the fan was placed directly next to the main haulage road. The variable frequency fan drive was located in a niche next to it that was not directly ventilated. This control panel failed several times due to electrical faults in the circuit boards (**Fig. 15**). More detailed examinations revealed deposits of soot dust on coated circuit boards. The protection provided by the lacquered conductor tracks was not sufficient. Even with a thin deposit, the dust was so conductive that a short circuit occurred in adjacent components. This could be proven by a test with a filter mat that was only a few days old. The cause was quickly found: Next to the fan, the main heading was sealed by an air door. However, this was passed several times an hour by a vehicle, which had to stay in front of the door for a few minutes each time. The vehicle was

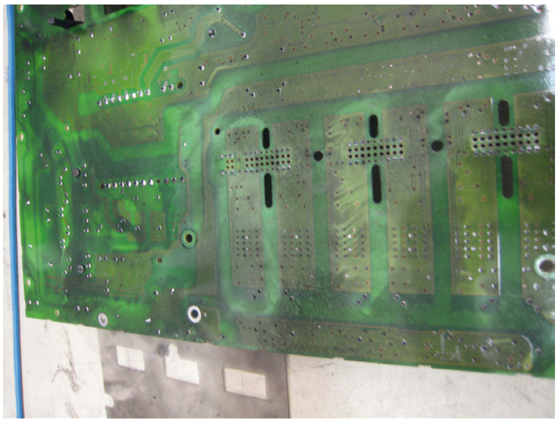

Fig. 15: Anhydrite mine – circuit board for fan controller

Fig. 16: Anhydrite mine – mine vehicle with sooty exhaust

an old traction unit without a particulate filter system (**Fig. 16**). After passing through the door, the exhaust fumes dispersed and were trapped in the niche, where they gradually settled. If the door had been moved just a little, the control niche had been slightly ventilated or the cabinet had been sealed appropriately, there would have been no damage and thus no failure. These operating conditions had not been taken into account during the planning phase and the customer had not made any special demands on the control system beforehand. Technical solutions to prevent such damage are certainly available. These include suitable filters and pressurised systems. However, most operators, at least in the case of non-system-relevant plants, would prefer not to make such investments. A cost analysis was not carried out for the example described. Only the capital investment was considered. Nobody noticed that the electrician's shift had already cleaned and bridged the control cabinet three times. The investment in an expanded system would not only have reduced the total financial expenditure, but would also have made a contribution to sustainability by reducing the carbon footprint.

4 Chemical Exposure

Equipment is exposed to chemical attack, which of course varies greatly depending on use, operation and local conditions. Fans used on ships, e. g., must always be adapted to corresponding offshore conditions. Resistance to salty and humid air is essential. Similar requirements exist for main fans in salt mines when installed close to the shaft. Depending on the conditions of the supply air, penetrating moisture together with the salty air can cause corrosion as a consequence (**Fig. 17**). In this case, it is not sufficient to just paint the steel components as normal. Other plastic components, such as vibration dampers and compensator components, must meet certain material requirements and must not age prematurely. The materials in the construction of the units must be selected carefully. Not all stainless steels can be used in salt, nor in return air systems containing enriched sulphur gases. If the composition is not clarified in advance, there is a risk of very rapid corrosion of various materials. System components that are not operated permanently, such as shut-off and inspection flaps or brakes, become pre-damaged and no longer function properly.

Fig. 17: Surface corrosion caused by moisture and salt-laden air

In a few cases, a chemical reaction of different substances and materials used is possible. No plant or lubricant manufacturer can test all chemical compositions. Reactions of new separating agents or lubricants with certain local air contents are unpredictable. Especially in mining, each deposit provides for a different chemical composition of the air without violating limits of certain pollutants. Nevertheless, it is unavoidable that components can be chemically damaged. The number of chemical particles is particularly high inside the fan due to the volume of air moved (**Fig. 18**). As a result, the components are subjected to a far greater concentration than might be assumed at first glance. In principle, the chemical resistance may be the same as for other components, but the time factor exponentiates the risk of damage.

A fan moves air that contains one of the essential factors for corrosion: oxygen. Thus, only a few more components are needed to achieve a real potential for corrosion.

Fig. 18: Chemical corrosion inside a mine fan

5 Explosive Gases

There are many sets of rules for handling explosive mixtures in the conveying stream. The exact design requirements for electrical and non-electrical equipment are specified in standards and directives, so they will not be discussed further here. The machinery manufacturer is required to have the explosion-proof design confirmed by a certified third party body and thus guarantees the mitigation of the risk. These requirements are in addition to those already described, so that the tests relating to material pairings and material properties are even more extensive. Explosion protection, namely the prevention of an open ignitable spark, must be guaranteed in accordance with the applicable regulations. In particular, the focus is on the necessary equipotential bonding, which may not only affect the individual machine. Elements with a large surface area and incorrect painting or components that are not earthed represent an equally large risk potential that the operator must consider in his overall risk analysis.

6 Conclusion

Practical examples show that the operator must always consider the entire system from different perspectives. In some cases, this gives rise to new types of faults that neither the machinery manufacturers nor the machine operators can recognise in advance in the normal framework of 'state-of-the-art' engineering.

However, being 'fit for mining' generally applies to both the men and the machines that have to work underground – and here ventilation plays a special role in the context of their operating conditions and environment. And the experience that has been acquired in this area can of course prove useful when installing fan systems for the excavation and subsequent operation of tunnels.

7 References

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