THE HISTORY OF MINE FANS IN SOUTH AFRICA

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In this paper the authors endeavour to give an accurate account of the history of mine ventilation fans in South Africa over the past century. It is inevitable that there will be a number of omissions concerning the development of mine fans and it is hoped that others will be inspired to contribute additional information on this interesting subject which could be published at a future date.

Ventilation by natural draught appears to have been the accepted ventilation method in South African gold mines from 1886 to the end of the nineteenth century.

These mines were small, in which the average stoping depth was about 240 metres and the deepest shaft 1 000 metres. Two shifts of ten hours or more were common. Blasting was done on an ad-hoc basis, and there was no blasting interval permitting work to be carried out continuously in development ends.

This situation persisted until it was recognized that largely for health reasons improved ventilation was necessary, leading to the introduction of mechanical ventilation in South African mines.

The use of fans thus replaced natural ventilation and for convenience their development is discussed in terms of main and auxiliary fans.

Main Fans

Mechanical ventilation was introduced on the Witwatersrand in 1908, when a fan was commissioned on the East Rand Proprietary Mines.[2] An interesting aspect of these earlier fans was their size. They were generally very large and ran at low speeds. Typically they were manufactured in sizes from 6 to 13,7 metres in diameter with running speeds of between 0,67 and 1 rev/s.[3]

One of the early makes of fan was the famous Walker Indestructible fan which had an impeller with eight backward curved plate blades, reinforced with angle sections. (Fig. 1). In 1932 such a fan was installed at the Government Gold Mining Areas, and had an impeller of 9,14 metres in diameter, and was designed to move 425 m^3/s air at 2,8 kPa, driven by a 1 120 kW compound engine. The fan casing was brick and concrete and was arranged so that the fan could be used as an upcast fan under normal circumstances, but the flow could easily be reversed to blow air down the shaft if required, in the case of an underground fire.

At the turn of the century Samuel Davidson developed the forward-curved multi-bladed centrifugal fan to handle hot air for tea drying. This fan, the Sirocco, was named after the hot wind which blows from the coast of North Africa across the Mediterranean. The impeller had a large number of long, narrow, forward curved blades. It was basically a high specific speed fan, and the relatively small impeller could move a large volume of air. By 1932 a number of these fans, varying in diameter from 0,9 to 4,6 metres were in operation in South African mines. They were extremely reliable and some of them are still in use on collieries today.

The next major development took place when F.A. Steart of Northfield Colliery in Natal experimented with propeller fans. His first fan consisted of six two-bladed Curtis aircraft impellers manufactured from wood. The impellers were 2,54 metres in diameter, mounted in series on a single shaft and driven by a 52 kW motor running at 12,83 rev/s.

Steart found that re-entry of the air took place in the centre region of the discharge, and overcame this problem by mounting a small propeller at the discharge end. This succesfully prevented re-entry and improved the fan performance. Tests with six impellers arranged in this manner were carried out and the fan handled approximately 74 m^3/s at 0,6 kPa. Greater volumes of air were handled with rotors running at 14,83 rev/s. At a later stage these rotors were replaced by four-bladed propellers, thus reducing the number of propellers required. Many variations of this design with up to fourteen stages were installed, some with steel bladed propellers.

A number of such propeller fans built with adjustable pitch blades fitted in cast steel bosses were used on Crown Mines, and were manufactured in the mine workshops. Tests on these fans showed that the efficiency improved from 5% to about 60% as the number of blades was increased from 2 to 32.

Propeller fans were however rather clumsy units with their many stages. They were also inefficient. But, the straight through flow configuration was a big attraction for underground installation because of the smaller and

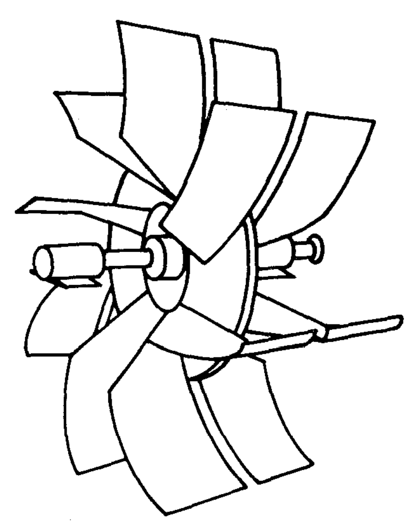

Figure 1

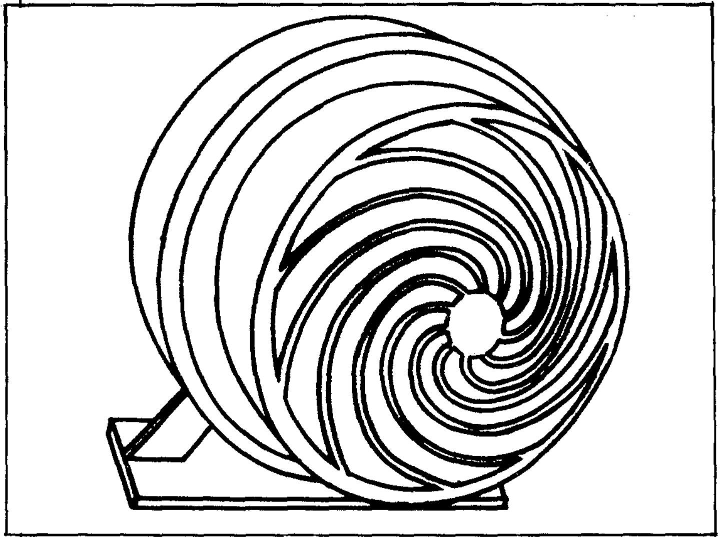

Figure 2

less complicated excavations required in comparison with centrifugal fans. The search continued therefore for a new, efficient design of axial flow fan.

The first noteworthy modification of the Steart fan was the unit developed by Adamtchik. This design was used in the Aeroto and Aerex fans from 1928 onwards. Both these units consisted of an impeller with fixed pitch blades followed by a set of co-axial air straighteners. This construction however limited their flexibility since a variation in duty could only be obtained by a variation in speed. Most of these fans were therefore equipped with V-belt drives. Another way of obtaining a different duty from the same fan was to fit another set of blades cast at a different pitch angle, and there was at least one instance on the Witwatersrand where a Ward-Leonard drive system was used to enable the speed to be altered. This however turned out to be inefficient and costly.

From the mid-thirties onwards these fans became very popular on the South African mines, especially for underground ventilation, where they required less space and weighed less than centrifugal fans. Main ventilation fans varied between 1,78 amd 4,84 metres in diameter and had one, two or three stages to suit pressure requirements. Underground booster fans varied in size from 1,27 m to 3,81 m diameter. A typical main surface fan of the modified Steart design was installed at Modder 'B' in 1935 for a duty of 70,8 m^3/s at 0,75 kPa. This fan had a 2,29 m diameter rotor operating at 9,67 rev/s. Still operating at East Rand Proprietary Mines is a similar 2,24 m diameter two-stage fan that was installed in 1938.

By 1940, the total volume of air supplied by main fans for ventilation purposes in forty-one producing mines, was about 8 350 m^3/s. The average volume of compressed air supplied at the same time was about 444 m^3/s of free air. By 1944 the total downcast air in the 47 mines then in existence from Heidelberg to Klerksdorp was 9 400 m^3/s, with several hundred auxiliary fans required.

On some mines there were as many as twenty main fans, varying from just under 1 metre to over 9 metres in diameter. In general capacities ranged from 230 to 280 m^3/s at a pressure of 0,5 kPa to 0,75 kPa, with two or three fans having capacities over 470 m^3/s at a pressure of about 2,5 kPa. A variety of fans were used including Aerex, Aeroto, Safanco, Sirocco, Demag, Keith Blackman, Thermotank, Macard, Hohenzollern and Walker fans.

The Walker Indestructible centrifugal fan was still popular as late as 1945. its one big disadvantage was its limited flexibility. However, this deficiency was overcome with the development of the adjustable tongue or cut-off which allowed the duty of the fan to be changed over a considerable range. An example of this fan design was a Westphalia Dinnendahl "Hohenzollern" adjustable tongue fan installed at the May shaft serving Daggafontein and East Daggafontein mines. The fan duty could be varied between an initial 200 m^3/s at 2,5 kPa and a final duty of 354 m^3/s at 2,5 kPa; its impeller diameter was 9,14 m and its operating speed was 2 rev/s.

It was usual practice in those days to use steam engines to drive these large, slow running fans, and the above fan was no exception. It was driven by a tandem compound condensing steam engine with a low pressure engine of the uni-flow type. The cylinders were 647,7 and 1257,3 mm in diameter with a stroke of 1016 mm. Steam pressure at the engine was 1,378 MPa at a superheat of 37,8°C. At No. 4 Circular Shaft, Brakpan Mines, a similar fan was installed with a capacity of 500 m^3/s at and 4 kPa, and was driven by a Metropolitan-Vickers steam turbine through double reduction gearing and a Bibby Coupling. The full speed of the turbine was 83,33 rev/s. The steam pressure was 1,654 MPa at a superheat of 121°C.

The Dickson screw fan was developed in South Africa and was used at Crown Mines where it was manufactured in their own workshops. The impeller blades were bent from steel plates and rivetted to the hub. These fans were very robust but they could not achieve high efficiencies. By 1945 Crown Mines had nineteen of these units installed with 2743, 2794 and 2972 mm diameter impellers.

Towards the latter part of the 1950's, fan pressure requirements started to increase and in 1957 Rand Mines issued an enquiry for four fans, each to be capable of handling 140 m^3/s at 8 kPa with an operating duty of 212 m^3/s at 6,75 kPa. Western Ultra Deep and Vaal Reefs soon followed with fans of similar duties, requiring single inlet, backward-curved, aerofoil-bladed centrifugal fans running at top speeds of around 135 m/s.

Prior to this an aerodynamicist, Levachic, had tried to develop a centrifugal fan with adjustable pitch blades, cantilevered from the backplate,. The adjustable pitch idea could not be made to work. But, it was soon realised that, from a structural point of view, the geometrical configuration had considerable advantages over standard designs. One company in fact, used this design concept in the manufacture of the impellers for the above fans. The basic construction utilises a blade with a much greater chord thickness at the backsheet than at the shroud, and inclined at about 10 degrees to the backsheet. This allowed the impeller to be constructed from mild steel, which was advantageous, as high tensile strength steels were not in common use in South Africa in those days. Furthermore, mild steel allowed for site repair work to be carried out without stringent welding procedures.

In these designs, the impellers of large single inlet main surface fans were initially mounted between the bearings. Due to the hostile operating environment of the non-drive end bearing this concept was changed to an overhung arrangement.

The first large centrifugal main ventilation fans supplied by James Howden comprised eight 4089 mm diameter fans with aerofoil blades and were installed in the Welkom area during 1959. The impellers were overhung at the shaft ends, and were the first of many impellers supplied in South Africa utilising high tensile strength steel which allows for a lighter impeller for a given duty.

Improvements to centrifugal fan design continued with many fans of this type being supplied to the mining industry.

In 1975 the main ventilation fans at Elandsrand Gold Mining Company were installed, and had 4500 mm diameter impellers running at 9,83 rev/s. The design duty was 350 m^3/s at 9 kPa and the stall point occurred at 230 m^3/s and 10,5 kPa.

In the same year, however, Unisel Gold Mine installed two 2800 mm diameter, single stage two-speed, variable pitch axial flow fans. Their design duty was 220 m^3/s at 5 kPa. The broad operating spectrum specified was best accommodated economically by the flexibility offered by an axial flow fan with variable pitch blades.

Depending on the operating conditions specified, the main ventilation fans presently supplied to the mining industry are either of the centrifugal or axial type. they are electrically-driven and usually situated at the top of the upcast shaft.

Auxiliary Fans

Venturi blowers were first introduced on the Witwatersrand as early as 1923 by Flugge de Smidt to ventilate those places where air would not naturally enter.

In the same year the Joint Committee comprising the Chamber of Mines Department of the Union of South Africa and the Transvaal Chamber of Mines was appointed to investigate the ventilation of development ends. The introduction of the Venturi blower made it possible to implement the recommendations of the Joint Committee with great improvement in the ventilation of development ends. In the following few years, hundreds of development ends were equipped with these blowers. Another type of blower was the Coppus Vano Blower with discharge guide vanes and driven either by an electric motor or by a compressed air turbine. It could deliver up to 24 m^3/s at 0,25 to 1,75 kPa.

Auxiliary ventilation work was also performed by the Westphalian Duct Ventilator (Flottmann) which had fixed inlet guide vanes and was driven by means of a compressed air turbine. An unusual type of auxiliary ventilation fan, the Schlotter fan, had a five-bladed screw type impeller and ten curved discharge guide vanes which were designed to set up a rotating motion of the air converging to a jet area about half the impeller diameter beyond the guide vanes. (Fig. 2). This fan could deliver about 1,18 m^3/s through a 1525 m long duct.

In 1936 H.G.W. Pillman started a company which he called Safanco. The first Safanco product was a compressed air driven auxiliary ventilation fan. A novel feature of this fan was the turbine mounted directly on to the circumference of the impeller, resulting in a very compact unit. As well as being sold locally, these fans were also exported to Australia and the Belgian Congo (now Zaire). The first Safanco auxiliary ventilation fans had motor housings which rotated around a stationary shaft. The fan impeller was a patented design and was bolted directly to the rotating motor housing.

In 1937 Curt Keller, Chief Engineer of Escher-Wyss, published a book containing the results of his research on axial flow fans (4). Not long after its inception, Safanco started to design and manufacture axial flow fans with adjustable pitch aerofoil blades and fixed guide vanes based on Keller's principles. Safanco also designed and built electric motors to drive these fans. Not only were thousands of 3,75 to 15 kW motors built to drive auxiliary ventilation fans, but they also built a few slip-ring motors of 225, 300 and 560 kW capacity to drive main ventilation fans.

By 1945 the earlier mentioned compressed air driven Coppus Vano and Schotter auxiliary fans had been mostly superseded by more efficient and compact KKK, Downright, Aeroto, Rateau and Safanco compressed air driven fans. However, the overall efficiency of compressed air driven fans is far less than that of electrically driven fans, and most of these have been replaced by electrical fans.

CONCLUDING COMMENTS

Along with this brief history of fans on South African mines, it is perhaps appropriate to mention some design tools and methods which have been developed through the years.

The first large fans were designed with a substantial safety factor to cater for the lack of tried and tested design criteria. Strength calculations had to be performed by hand, sometimes with the aid of logarithm tables and later the slide rule.

Today, computers are used to optimise the selection of fans for given duties, stress calculations, selection of materials, bearings and improving fan design, for example, fan curves are drawn neatly and accurately on a plotter driven by a computer. CAD systems are used for drawings, plate nesting and other fan components previousely draugthed by hand. In addition Finite Element Analysis methods are used extensively to determine stress patterns in impellers: this enables the fan engineer to design lighter but stronger impellers while at the same time paying special attention to the most highly stressed areas.

It is also usual practice at present to install electronic devices for monitoring vibrations and bearing temperatures to anticipate fan failure and allow for timely repairs and the purchasing of spares.

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