Comments to possible jet fan energy efficiency limits 2018/2020 in the revision of EU directive 327/2011

Summary

The main use of jet fans in the European Union is for tunnels (mainly road tunnels), metros and parking garages. Both in terms of numbers and energy consumption these 3 markets in our estimate make up 95% of jet fans sold. In terms of energy consumption the tunnel and metro applications should dominate, since the parking garage jet fans, despite their fairly large numbers are on average 10 - 20 times smaller than the average jet fan and rarely operate, since they are mainly installed to operate in case of fire. We would recommend not to set limits for jet fans and to exclude them from the scope of the regulations.

Contrary to most uses of fans jet fans are mainly bought by with public funds and their specification based on national and international rules and guide lines (e.g. RABT). It is a very transparent market where it is customary for almost all projects that a performance test which includes the comparison of performance versus energy consumption is measured in each case. If there is a need to improve the energy consumption of jet fans introducing life cycle cost comparison into the public tenders seem to be a better way than setting efficiency targets, especially since the actual system performance of the jet fans do not correlate very much with the proposed Total Fan Efficiency measure used in the report. On the contrary it seems that many high efficiency solution would arbitrarily be banned, which seems counterproductive.

Because Jet fans have to be able to operate from -50°C continuously to 600°C for 2 hours and be up to 100% reversible at least a 0,85 x 0,85 compensation factor would be required effectively making the limits meaningless.

Even if a limit was to be set it should be very different from the curves shown in the report as they do not seem to realistically represent the market and to take into account the variations required by the current rules and guide lines.

Introduction

The discussion document by VHK dated 21.11.2014 and the presentation at the 2nd stakeholders meeting dated 23rd of January 2015 both had in the Annex curves for jet fans, however without directly suggested new limits.

We would like to recommend that jet fans are excluded from the scope of the regulation or at least that this issue is studied further before efficiency limits are set. We believe there are a number of reasons for this:

1) Unclear data used in the report
2) Unclear definitions make comparisons near impossible
3) Complicated correlation between real performance and efficiency values
4) Different temperature ranges make comparisons meaningless
5) Produced thrust versus actual thrust in the tunnels are very different
6) Very limited run time make impact negligible

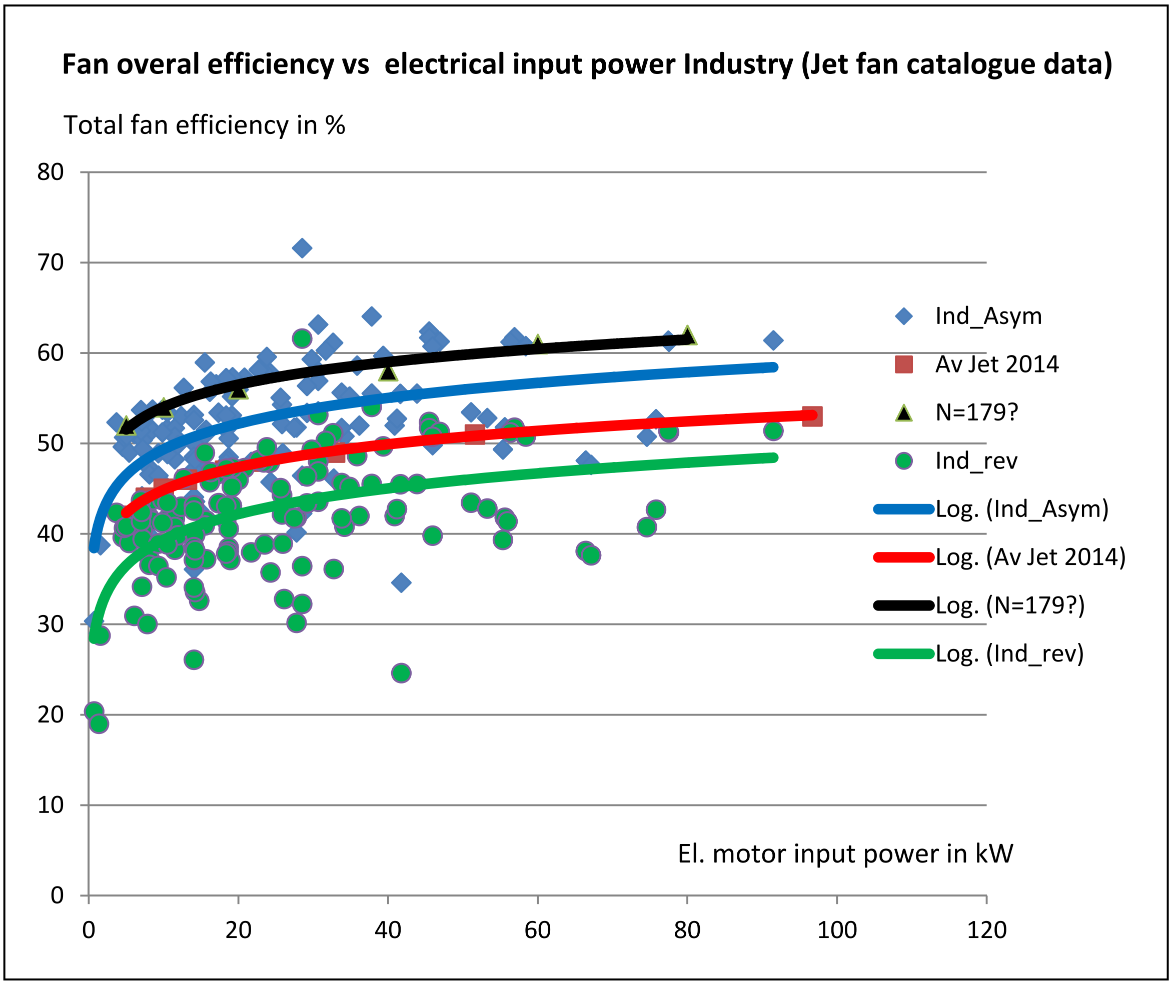
7) Transparent market with its own extensive guidelines and regulations

Below we have tried to deal with each issue in turn.

1) Unclear data

In terms of data there seems to be some confusion. In the report to the second stakeholder meeting there is mentioned something called "n=179" (page 46) and something called "Average Jet 2014" (page 47). We believe there must be some mistake in the N=179 data. Might it be that the motor power values are shaft power and not electrical input power, since in the catalogues no electrical input power data is given?

Below is shown the comparison of the catalogue data (analyzed by Witt) of the four leading suppliers for asymmetrical jet fans **(blue),** the approximate data for symmetrical jet fans **(green),** the Average Jet fan data 2014 **(red)** and the n=179 curve **(black)**.

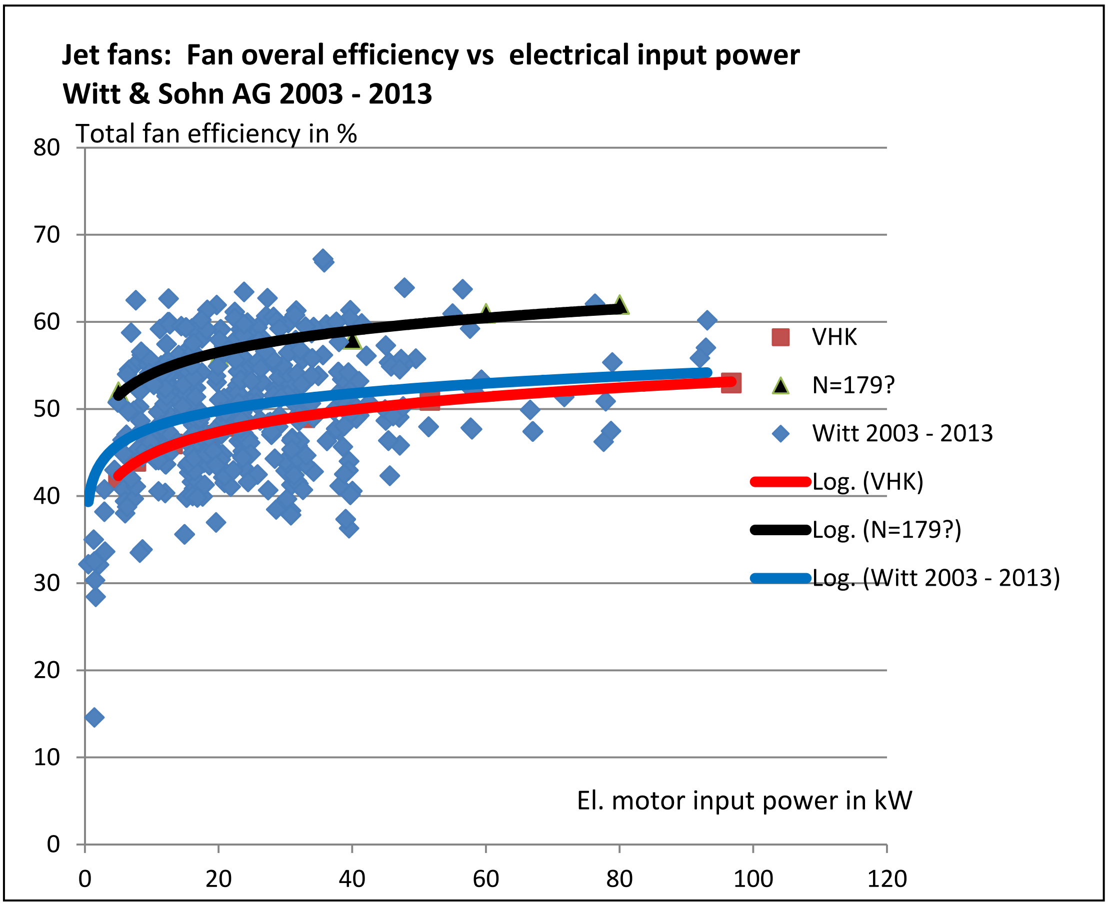


It should be immediately obvious that

- The **red** line seems to be the average line between the **blue** and **green** lines for the asymmetrical (unidirectional) and the symmetrical (reversible) jet fans.
- There are many dots below the "trend lines"
- The **black** line seems to be much higher than the published catalogue data. It probably should be discarded.

What is important to understand is that the various dots do not show different fan types; essentially for the four manufacturers they are offering just one unique type of fan. The variation is the fan diameter, the steepness of the blade angle and the length of the silencers. So just 4 fan designs are responsible for all the dots in the graph!

Assuming that catalogue data can be manipulated (either to make them seem better or worse) below is shown the actual performance data of Witt & Sohn in realized projects from 2003 to 2013. (Mixed symmetrical and asymmetrical data including fans for 250°C, 300°C, 400°C and 600°C.)



The graph shows that the **red** line posted as the "average jet fan performance 2014) is close to the average Witt, **blue** line, has experienced as well.) As mentioned above, the **black** n=179 line is too high and does not reflect the actual performance of actual jet fans.

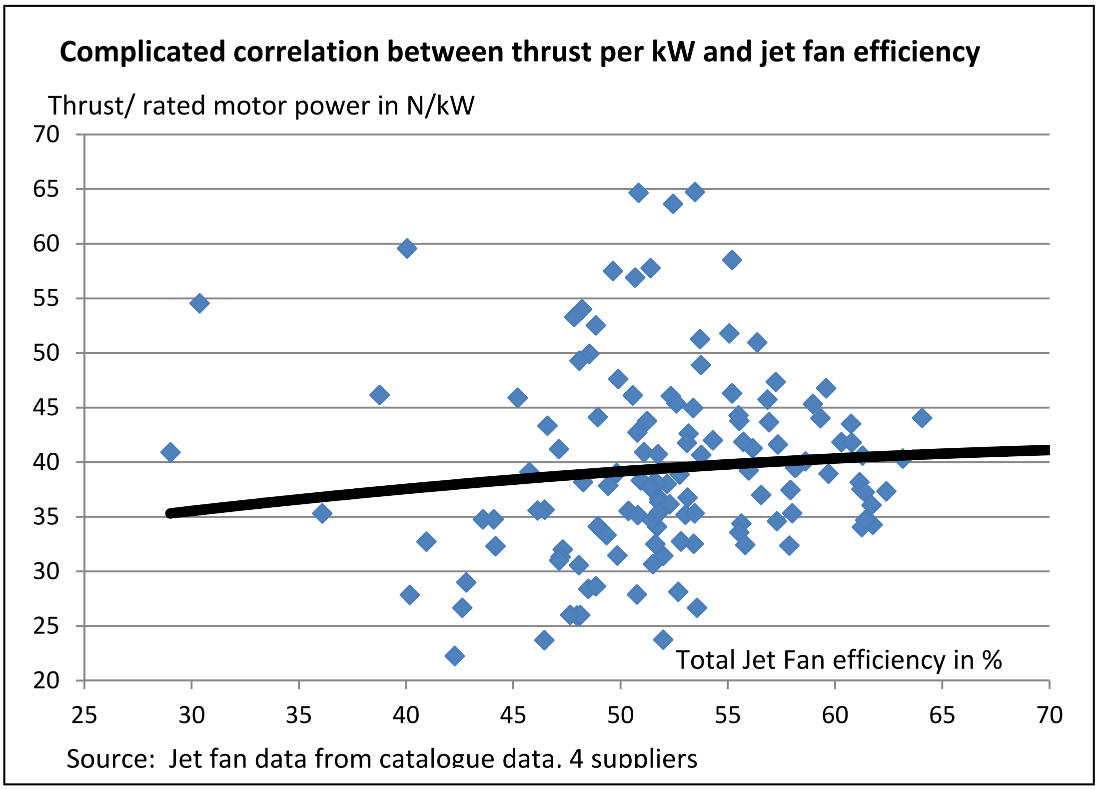
When analyzing the data more closely it can be seen that many of the data points below the average line are projects with special needs, almost all are reversible jet fans and particularly high noise criteria were needed to be met.

2) Unclear definitions

The discussion paper did not offer any clear definition of a jet fan, nor was a measuring method proposed. Before a limit can be set such definitions are necessary. Below are examples of some of the most common variations.

- Contrary to what the paper described, both axial and centrifugal fans are used as jet fans. Centrifugal fans are more unusual due to more difficult noise attenuation and are difficult to reverse, but they have a good performance otherwise.
- Some jet fans have no silencers, some have just a silencer on one side, some silencers of for example 1 diameter length on both sides and some have silencers up to 5 - 6 times the length of the diameter. Sometimes the silencers are straight, but they can also be conical or bend or both. There is of course a significant drop in performance the longer the silencer is. The configuration of the holes, the type of fleece specified etc. can also play a role.
- Today jet fans are typically built as reversible jet fans in tunnels, but in parking garages for example they generally are built non reversible, which have a slightly higher performance.
- Even when it comes to reversible fans there is a big difference in performance. An 80% reversible fan has an in general a higher performance (in one direction) compared to the often specified 100% reversible fan designs. The necessary extra pre- and post guide vanes cost efficiency. At least a 0,85 correction factor should be included.
- To reach really low noise levels sometimes silencers with pods have to be build.
- The location of the jet fan also influences the design. A jet fan for a narrow railway tunnel will experience a much higher pressure pulse compared to your average automotive tunnel and therefore has to be built with stronger internal support structure, which obviously influences the performance.

3) Complicated correlation between real performance and efficiency values.



The purpose of a jet fan is to introduce maximum thrust into the air steam of the air it is supposed to move. Contrary to the belief of most people, the smoke is not transported from

fan to fan, when the jet fans act as smoke extraction support fans. Instead it is the task of the jet fans to exert a force parallel to the tunnel walls and get the whole column of air to move.

In the above graph is shown the relationship between the actual thrust per kW (rated) power introduced by the fans into the air stream versus the Total Fan Efficiency measure used by VHK in their report. As can be seen there is no real correlation. There are many reasons for that. The data compares small and large jet fans with long and with short silencers, with large and small motors, different fan speeds, reversible and non reversible etc. Particularly the size is problematic, because although there is physically a clear correlation between fan size and performance this often can't be used. The maximum fan size that can be installed in a given tunnel is given by the free space inside of the tunnel, which allowing for cars and trucks having to use the tunnel, by the nature of things, naturally is very limited. So the fan size is by and large set by the public tender of the various government agencies, who ultimately are behind the projects.

Many fans that on paper seem to have a "bad" efficiency in actual fact have a very good output ratio. This suggests that using "efficiency" as a % with a similar definition as used for axial and centrifugal fans is wrong. By setting an arbitrary number, for example on the graph at 53, this would eliminate a significant number of very good fans. In all probability the net effect on energy efficiency would be negligible or even negative by such an approach.

4) Temperature rating

Depending on the customer's specifications mainly determined and set by local and/ or national regulations most jet fans have to be temperature rated. Typical ratings are F300, F400 and increasingly F600 according to EN12101-3. This means that the fans have to be tested and certified in an independent laboratory, which in turn is accredited by the EU. The test involves heating up the air passing through the fan within a given minimum and maximum timeframe (around 10 minutes), stopping the fans completely for 2 minutes and then keeping the air flow at the predetermined temperature for 2 hours for 300°C, 400°C or 600°C for the relevant F300, F400 or F600 rating.

In order to be able to achieve this type of temperature resistance the fan designs have to be modified. Typically the air gap has to be increased, special materials have to be used, and special motor supports designed and special motors installed. Unless special categories are made for each possible temperature class or special correction factors applied, then the jet fan limits would have to take into account the highest possible F rating. A minimum correction factor should be 0, 85. Since all these fans potentially also will have to be 100% reversible, in many cases, the additional 15% allowance for that must be added as well.

5) Produced thrust versus actual thrust

Jet fans do not operate in isolation but are part of a larger ventilation system, as are most fans. The difference is that how the jet fans are built and the additional features added to their design have significant impact on the real, overall energy efficiency of the fans. A traditional jet fan, which blows the air in a straight line will create very large losses, up to 60 % of the total thrust generated, in the structure where is installed. For example losses from the friction along the tunnel walls, typically 10 - 15% of the output energy; back ground

velocity losses, typically 10% of the output energy; impulse losses against the ceiling right behind the fan outlet, typically 10-15% of the output energy and if the fans are installed in niches a further 10 - 30% impulse losses.

These types of installation losses are of one or two orders of magnitudes larger than the efficiency improvements which are being discussed in the regulation. By adding guide vanes or even more efficiently by bending the silencers away from the installations, almost all of these losses can be avoided. However when measuring the efficiency these improvements are not taken into account in the formulas. Setting an efficiency measure that does not explicitly include the energy benefits from the design would seem counterproductive.

6) Limited run time

Most jet fans are dual use fans which provide ventilation in normal conditions, with only a few fans operating, often at low speeds. When there is a need for increased ventilation, typically when there is a fire or a traffic jam with increased CO/ NOx levels, more jet fans are started to increase the total flow rate.

A few decades ago, when sizing the ventilation systems for tunnels traffic jams were the dimensioning scenario, mainly because the exhaust from trucks and cars was much higher and it was necessary to remove the CO/NOx. The fire scenarios were also less demanding compared to today, because the assumed fire sizes typically were smaller than today. Today the rules have taken into account the much cleaner exhaust from the cars, so when ventilating for traffic jams the need of air has been reduced. On the other hand, the catastrophic fires experienced in for example the Mont Blanc tunnel has increased the awareness of the risk of fire. Today in almost all projects it is the fire scenario that is the dimensioning factor for the ventilati0on systems in tunnels, metros and car parks.

Since thankfully large fires are very rare this means that with few exceptions the average jet fan has very limited operational hours. Increasingly the main problem with the longevity of these fans is that they even do not reach minimum operating hours every year for proper lubrication of the bearings and only are started during the annual maintenance. The energy saving impact of optimizing the energy efficiency of this type of emergency equipment is therefore rather limited.

7) Transparent market

The main issue for the whole energy efficiency regulation is in our view one of lack of market transparency for the customers and the regulators. It is very difficult for almost all customers to verify the performance data of the fans in the absence of publically readily accessible test laboratories. Also, at least so far, there has been no market surveillance.

For jet fans there is a very different situation. The customer has a 100% ability to verify the data provided. All dual use jet fans are subject to the EN12101-3 regulation which requires a fire test including the power consumption. In addition it is customary for the customers to ask for a performance test of the fans prior to shipment. While for individual axial or centrifugal fans for other uses this may be too onerous, the public nature of most jet fan

projects coupled with normally large numbers of identical fans, have made individual performance testing industry practice.

With the public being the customer in almost all cases (except for the very small parking garage fans) a much more direct control of the energy efficiency of jet fans is had through the fan specifications such as the *RABT* (Richtlinien für die Ausstattung und den Betrieb von Straßentunneln)/ (Guidelines for the equipment and operation of road tunnels), which in detail sets the selection criteria for the equipment used in tunnels and is used worldwide. Even when the customers are private public partnerships the same rules and regulations have to be followed and in general already today energy efficiency is at a premium. One good example of that is the Norwegian practice over many years to evaluate the tender submissions of fans using a predefined formula for life cycle costs.

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Instead of setting arbitrary limits in a general EU directive it seems more sensible for the national governments to continue to improve their specific specifications and rules and in particular to include life cycle cost in their own purchasing procedures. For jet fans there does not seem any need to make additional rules to improve an already well functioning system.