**\subsection**{The probability of interruption} **\label**{sec:DiscIntChan}

When analysing the results presented in section \ref{sec:interChance} it is important to link them to past experiments. A short summary of previous experimental results is presented in appendix \ref{app:PrevReleEx}, and should be consulted when reading this part. For more information regarding past experiments, see article \cite{bib:CIAMVLBS} and \cite{bib:AFIMVLBA}.

Overall geometry \textit{a} performed better than geometry \textit{b} for both interruption test performed in this study. The results from the 400 A interruption test is indicated in figure \ref{fig:successRate400A}. It states that geometry \textit{b} interrupted 100\% of the tests at 0.7 bar upstream pressure, while geometry \textit{a} interrupted 100\% of the tests at 0.8 bar upstream pressure. This is strange considering that geometry \textit{a} have a bigger $A\_\mathrm{{contact}}$ than geometry \textit{b} resulting in a bigger air flow. Geometry \textit{a} have a bigger nozzle diameter than geometry \textit{b} and might explain that the increase in volume flow of air from geometry \textit{b} to \textit{a} do not result in a improved interruption probability, since the air flow might not be efficiently guided on the arc at 0.7 bar. However, the difference in success rate cannot be considered significant, since the interruption results for geometry \textit{a} at 0.7 bar was 90\%. At a upstream pressure of 0.6 bar geometry \textit{a} interrupted close to 80\% of the test, while geometry \textit{b} interrupted 20\%. If the 50\% success rate in evaluated geometry \textit{a} performed better than geometry \textit{b}, this is like expected, where \textit{a} had a upstream pressure of approximately 0.47 bar and \textit{b} had a upstream pressure of approximately 0.64 bar. If equation \eqref{eq:Bernoulli} and \eqref{eq:flowRate} is combined the relationship presented in equation \eqref{eq:flowRateprop} is obtained.

\begin{equation} **\label**{eq:flowRateprop}

Q \\ \alpha \\ \sqrt{\Delta p} A\_\mathrm{{contact}}

\end{equation}

This clearly states that the volume flow \textit{(Q)} will be larger for geometry \textit{a} than geometry \textit{b}, since $A\_\mathrm{{contact}}$ is larger when the pressure difference $\Delta p$ is kept constant.

Previous tests have indicated that a nozzle with a small diameter and short length should be chosen. This is because a too wide nozzle may lead to a too slow air velocity and may cause the air flow to pass around the arc. However, a too narrow nozzle might cause the arc to clog it, and preventing an efficient flow of air. The nozzles chosen for this experiment has a diameter of 10.4 mm for geometry \textit{a} and 8 mm for geometry \textit{b}, which is relatively large compared the pin contact, when compared to previously tested geometries. Therefore, it is expected that the current geometries should perform poorer than the test results presented in figure \ref{fig:resultsCIMALBS}.

In figure \ref{fig:ninaBryt}, it can be observed that if the diameter of the pin and nozzle is reduced, higher pressures are needed to perform a successful interruption when the pin is outside the nozzle. This is due to the volume flow which is limited by the smallest cross-section of the contact geometry. For the previous tests presented in appendix \ref{app:PrevReleEx}, $A\_\mathrm{{contact}}$ is the limiting cross-section when the pin is outside the nozzle, when the pin is inside the nozzle $A\_\mathrm{{ring}}$ is limiting. In the current geometries $A\_\mathrm{{contact}}$ is smaller than $A\_\mathrm{{ring}}$ and $A\_\mathrm{{nozzle}}$, and is therefore the limiting cross-section. For the tested geometries $A\_\mathrm{{contact}}$ has a diameter of 4 mm for geometry \textit{a} and 3 mm for geometry \textit{b}, which is considerable smaller than previously tested geometries. Hence it is possible to presume that the current geometries should perform poorer than the geometries presented in appendix \ref{app:PrevReleEx}.

If the test results are compared to the results from \ref{fig:ninaBryt} it follows the same trend as obtained from that experiment. At a current of 400 A, the smallest geometry, which had a contact diameter of 6 mm from figure \ref{fig:ninaBryt}, interrupted all the tests successfully at 0.35 bar upstream pressure. If the 50\% success rate is used geometry \textit{a} interrupted 50\% of the tests at approximately 0.47 bar upstream pressure, while while the one presented in figure \ref{fig:ninaBryt}, denoted as \textit{a}, used 0.2 bar. In equation \eqref{eq:combiGeo} this geometry is compared to geometry \textit{a} at 50\% success rate based on the difference in volume flow with equation \eqref{eq:flowRateprop}.

\begin{equation} **\label**{eq:combiGeo}

\frac{Q\_{d=6 mm, 50\%}}{Q\_{d=4 mm, 50\%}}=\frac{\sqrt{\Delta p\_{50\%}} A\_{contact, d=6 mm}}{\sqrt{\Delta p\_{50\%}} A\_{contact, d=4 mm}}

\end{equation}

With numbers inserted in equation \eqref{eq:combiGeo} it results in a ratio of $\frac{Q\_{d=6 mm, 50\%}}{Q\_{d=4 mm, 50\%}}\approx 1.5$. Which means that geometry \textit{a} uses approximately 1.5 times less air volume than a previously tested design. With use of equation \eqref{eq:Bernoulli} the ratio of the maximum air velocity in the contact geometry can be obtained as $\frac{v\_{max, d=6 mm}}{v\_{max, d=4 mm}}\approx 0.65$. This means that geometry \textit{a} compensates for the 1.5 times smaller air flow with a 1.5 times higher air velocity compared to the smallest contact geometry in figure \ref{fig:ninaBryt}, at 50\% interruption rate. However, the poorer performance of the geometries tested in this experiment is probably not just due to lower volume flow of air, but also might be because of a slower air velocity inside the nozzle when compared to the other geometries. With equation \eqref{eq:VolumetricFlow} the ratio of the speed in the nozzle can be calculated to $\frac{v\_{nozzle, d=6 mm}}{v\_{nozzle, d=4 mm}}\approx 2.5$. This means that when the air flows in the nozzle, the air velocity is considerable smaller for geometry \textit{a}. This might partially explain the large difference in needed upstream pressure between the two geometries. The calculations above is only considered as approximations, and the numbers has huge uncertainties connected to them. This is because the equations are based on cold air flow without an electrical arc, but they might still be used to indicate a difference between the two tested geometries.

Further numerical analysis of these results will not be conducted, and the same trends pointed out above will apply to geometry \textit{b} as well. For the other geometries presented in figure \ref{fig:ninaBryt} the same trends will apply and can therefore be regarded with the same manner. The poorer performance for the geometries in this study was expected when compared to the ones in figure \ref{fig:ninaBryt}. However for the contact geometries used in this experiment it was hypothesized that: "Since the air velocity when the contact pin is inside the nozzle is the same as when the contact pin is outside the nozzle, it should have approximately the same probability of interruption". This was proven wrong, as none of the tests were able to interrupt the current when the pin was inside the nozzle.

For the geometries discussed above and presented in figure \ref{fig:ninaBryt2} the volume flow was limited by $A\_\mathrm{{ring}}$, since $A\_\mathrm{{contact}}$ was larger when the contact pin was inside the nozzle. Due to higher $v\_{max}$, but smaller volume flow it was expected that the geometries tested in this experiment where to perform about equal to the previous tests. Since it was not able to interrupt at all it might mean that the interruption rate inside the nozzle is not just based on the speed and volume flow of the air. It is suggested that the area behind the arc is also important for the interruption abilities of a contact geometry. This is because during an interruption it is important to not only cool the arc, but also remove all charge carriers between the electrodes. When interrupting in air this is mostly done by recombination of the ionized air, nonetheless, it will still be free electrons and metal vapour present even if the air recombines instantly after CZ, the recombination process also uses some time. Therefore it is essential to physically remove them from the gap between the electrodes. In a puffer concept and in the test switch this is done by blowing them away. If the area behind the arc is to small this effect might be less efficient and can hinder the charge carriers to be efficiently removed. The area behind the arc is described with $A\_\mathrm{{ring}}$ when the contact pin is inside the nozzle.

If $A\_\mathrm{{ring}}$ for geometry \textit{a} at 400 A is compared to the previously tested geometry, with a pin diameter of 6 mm at 400 A, the old geometry have a smaller ring area, which is 22 $\mathrm{{mm^2}}$, while geometry \textit{a} has a ring area of 72 $\mathrm{{mm^2}}$, which is relatively large in comparison. Still none interruptions were obtained. If the volume flow at the 50\% interruption probability for the previously tested geometry is compared to the highest pressure for subsonic air flow for geometry \textit{a} that was tested in this study, when the pin was inside the nozzle, the flow ratio will be: $\frac{Q\_{d=6 mm, p=0.23 bar}}{Q\_{d=4 mm, p=0.7 bar}}\approx 1.0$. That means that even when blowing with the same volume flow as done before still none interruptions were obtained. Experiments done with upstream pressure above 0.7 bar was conducted, none of these resulted in a successful interruption either. At this upstream pressure the air velocity crossed over to sonic speeds. When in the upstream pressure range with sonic speeds the equations presented in section \ref{sec:AirFlow} is not valid, and a cylindrical nozzle is not suited for these air velocities. Hence the results from these interruptions is not investigated further. If the same comparison is done to geometry \textit{c} from figure \ref{fig:ninaBryt2} to geometry \textit{a} from this test, which both have approximately the same ring area the flow ratio becomes: $\frac{Q\_{d=6 mm, p=0.20 bar}}{Q\_{d=4 mm, p=0.7 bar}}\approx 2.8$. This might indicate that even when the ring areas are the same, geometry \textit{a} is still blowing with too little volume flow to interrupt the arc.

Since blowing with approximately the same air volume, higher air speed and using a bigger area behind the arc do not improve the probability of interruption from the previous test it is difficult to explain why it was impossible to interrupt the current when the pin was inside the nozzle. It is probably due to a combination of the lack of volume flow and the relative limited area behind the arc.

When the pin contact was outside the nozzle it was possible to interrupt the current, however, when compared to previous test the lack of volume flow needed to be compensated with an increase in air velocity, resulting in an increase in upstream pressure. The needed pressure is high, and not in the pressure range usually applied in commercial load break switches. Nonetheless, it can be argued that in a situation where you have a powerful spring but a limited air volume it is possible to compensate the lack in volume by increasing the air velocity.

If the results from the 630 A test in figure \ref{fig:successRate630A} is consulted it can be observed that the pressure needed to obtain more than 50\% successful interruptions are above 0.7 bar and as expected higher than for the 400 A test. However, this means that the air velocity are in the sonic speed range. As mentioned before the equations applied is no longer valid, and a cylindrical nozzle is not suited. Therefore this results will not be analysed in the same way as the results form figure \ref{fig:successRate400A}. Successful interruptions was obtained when increasing the upstream pressure, which might indicate that when increasing the air velocity it can compensate for the lack of volume flow. Still no interruptions were obtained when the pin was inside the nozzle for this current range either. Geometry \textit{b} is still somewhat better than geometry \textit{a} at the 100\% interruption rate, but have a faster decline in success rate when the pressure drops. This is the same behaviour as in the 400 A test. For geometry \textit{b}, a fall in the interruption rate from 1 bar to 1.1 bar can be observed. This confirms the trend that high variations is connected with the results obtained through this experiment. The drop at 1.1 bar occurred for reasons unknown, in figure \ref{fig:rawData630AgeoB} it can be observed that 10 test where performed on this pressure. The first five tests were performed and all succeeded. Then as explained in section \ref{sec:procedure} the pressured was lowered to 1.0 bar and the success rate dropped to 70\%. This was a unexpected drop and five new test where performed on 1.1 bar where all the tests failed. The pressure was then increased and all the interruptions succeeded. It is assumed that the drop in interruption rate at 1.1 bar, was a result in normal statistical variations, it is also possible that the drop occurred due to damage contacts. The contacts was closely monitored during the rest of the experiments, this is discussed further in section \ref{fig:durability}.