

Advanced voice coil and wire technology for micro speakers and drivers

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Scope

The voice coil is a core and vital part in the motor/engine of the moving coil micro speaker and driver.

The VC transfers the audio power from a mechanical force to a sound pressure by means of bonding to a diaphragm pushing the air molecules resulting in the creation of sound.

The force in the voice coil is determined by $B \times L \times I$, where B is the magnetic field strength in the air gap of the magnet system, the voice coil is positioned in, L is the length of the wire in voice coil, and I is the electrical current flowing in the wire turns inside the air gap.

This sounds all very simple and straight forward, but a lot of advanced technology lies behind getting the maximum efficiency and reliability from the voice coil design. This White Paper describes all these parameters needed to be considered and optimized.

Optimization of fill factor (maximum conducting area in cross sectional cut)

As mentioned in the scope, a maximum fill factor in the magnetic air gap will ensure highest possible efficiency in the transferring of force from the voice coil to the diaphragm.

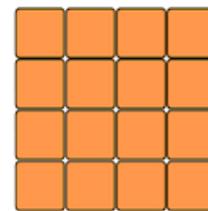
In Fig. 1 the extreme solution for a maximum fill factor is shown as a cross sectional cut of a voice coil, by using squared wire leaving no space between the windings for air and all space is utilized as conducting area (except insulation & bonding lacquer). This is a wire type typically used in large loudspeakers such as woofers in high end home theater devices, but for micro speakers and drivers for earphones, this is unfortunately not possible due to the very thin wires used here.

However, the fill factor can be optimized also by choosing the right wire diameter.

In Fig. 2 and Fig. 3 is shown two cross sectionals cut of two different voice coils having literary the same overall dimensions, one using a rather thick wire and the other using a thin wire.

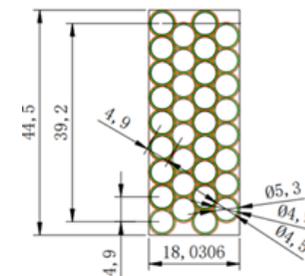
Fig. 1

RECTANGULAR WINDING WIRE



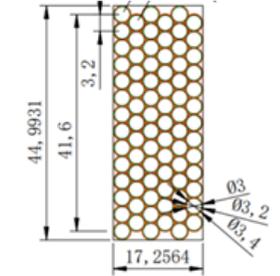
Rectangular wires allow compact winding

Fig. 2



Copper size=540.7462
Rectangle size=802.3612
Ratio=504.7462/802.3612=0.62739

Fig. 3



Copper size=572.555
Rectangle size=776.4189
Ratio=572.555/776.4189=0.7374

The wire types have the same thickness, isolation lacquer and bonding lacquer independent of the diameter of the conduction core, so one could immediately think the coil using the thicker wire would also have the highest fill factor. But this is not the case. The area of the encapsulated air between the windings is higher for the thick wire coil and therefore more than makes up for the less percentage of area of insulation and bonding lacquer.

The difference in the filling factor is not large, only approx. 1dB favorizing the thin wire coil but should nevertheless be considered. This is because there are other disadvantages associated with the use of a thick wire such as higher stiffness potentially causing Rub&Buzz. This issue will be dealt with in the later section 5 (wire manipulation).

The different form factors for voice coils

The principle in manufacturing the voice coil is winding on a polished spindle/mandrel, while hot air is blown on the coil for melting the bonding lacquer and thereby bonding the windings together for achieving a dimensionally stable coil.

For the processing of the different coil form factors such as circular, squared, rectangular, racetrack and ellipse, different methods are used (see Fig. 4, 5 & 6).

Direct Winding:

The spindle/mandrel is circular, squared, rectangular or racetrack shaped and no post processing is involved. - This typically applies to voice coils with larger corner radii or where a rather large cycling time can be accepted for the squared, rectangular and racetrack shapes.

Stretching:

The spindle/mandrel is circular the coil is subsequently reshaped into a racetrack, squared or rectangular shape through stretching instantly after the winding process while the coil is still hot. - This is typically used for voice coils with a small length- to- width ratio.

Fig. 4



Fig. 5



Elliptical stretching:

The spindle/mandrel is elliptical and is subsequently reshaped into a square, or rectangular shape through stretching instantly after the winding process while the coil is still hot. - This is typically used for voice coils with a large length - to - width ratio.

Fig. 6



Wire types

Basically, seven different wire types are used each optimized to the specific properties fostered to match requirements in the micro speaker or driver.

- » **No mark.** Copper conductor. If not specified, the conducting material is Copper.
- » **Al.** Aluminum conductor.
- » **CCA.** Copper-clad aluminum conductor with copper cross-section proportion of 15%.
- » **10% CCA.** Copper-clad aluminum conductor with copper cross-section proportion of 10%
- » **DHT.** Copper alloy conductor with higher tensile strength than copper. Abbreviation for High Tension wire.
- » **SDHT.** Copper alloy with higher tension than DHT. Abbreviation for Super High Tension.
- » **UDHT.** Copper alloy with higher tension than SDHT. Abbreviation for Ultra High Tension.

These wire types mentioned differ significantly in cost. The high-tension types are typically used in micro speakers, where the stroke of the diaphragm and hence the corresponding stroke of the wire ends leading to the solder spot is high and thereby stressing the wire ends significantly. This could else lead to fatigue issues resulting in an open circuit speaker.

The CCA versions are typically used in drivers for earphones, for optimizing the audio sensitivity due to the lower mass of these wire types.

Wire manipulation

As mentioned, the stiffness of the wire ends leading from the moving coil to the static solder spot at the frame of the speaker can cause unintentional performance in the form of pronounced noise at high sound pressure levels, commonly referred to as Rub&Buzz.

The wire ends movements are illustrated in Fig. 7.

Fig. 7

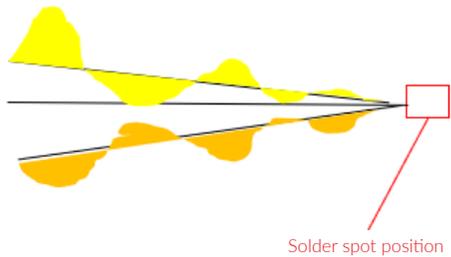


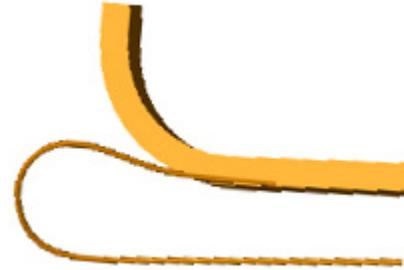
Fig. 8



The same stiffness of the wire ends can even lead to a non-working speaker, where the wire breaks caused by fatigue.

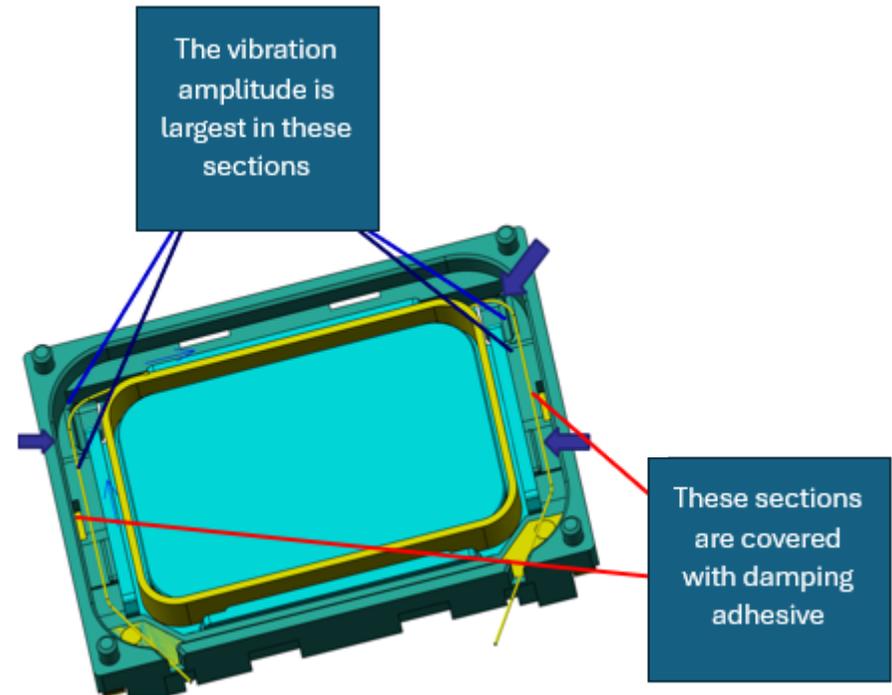
to avoid this situation, manipulation of the wire loop from coil to solder spot is crucial and requires excess attention in the design phase.

Fig. 9



Example of wire manipulation.

Fig. 10



Example of advanced wire manipulation using damping adhesive.

Conclusion

The voice coil is, as mentioned in the scope of this paper, a vital part of the micro speaker and in ear driver, which requires maximum attention in the design phase, especially in micro speakers as for some handles high power levels exceeding 2W having their miniature size in mind.

This leads to a very high stroke of the voice coil, which stresses wire ends and windings to a maximum. Knowing that micro speakers in portable devices are supplied with compressed sound signals with a very high rms value typically delivered from Smart Amps. This assures optimal loudness conditions for the listener but is driving the micro speaker to its limit both mechanically as well as thermal (voice coil temperature can reach 120° C).

Ole Wolff is a leading supplier of micro speakers and drivers having access to latest wire type technology as well as the advanced processes related to the manufacturing of state-of-the-art voice coils assuring a superior portfolio of these super performing miniature audio components.
