Precision Series White Paper

1.0 – Introduction: The Philosophy of Design

The design brief for the Precision Series was to create an elegant, contemporary line of products that would allow a wide sector of the marketplace to access key Wilson Benesch technologies, without compromising upon the fundamental philosophy of loudspeaker design that exists within the company.

By adopting key structural elements, componentry and design facets from the Geometry Series the design sought to build upon decades of work in drive unit technology, enclosure construction and numerous other technologies that are central to the success of high-fidelity audio reproduction achieved by award winning designs already created by Wilson Benesch. The compound benefits of this integrated approach are expressed throughout the Precision Series and was one of the principle reasons for the choice of the name. The complete control over every component in the synthesis of any product design is a considerable asset and strength that has been fostered by Wilson Benesch over three-decades. It is this capability that that has provided the foundation for the development of many small but very important and often innovative details that set a Wilson Benesch apart from other designs. The Precision Series is in every way a product built upon a strong legacy of innovation.

2.0 – The Precision Series Enclosure

Despite the apparently minimal, contemporary outward appearance of the Precision Series loudspeaker cabinet, the enclosure is in fact a statement in design and innovation. A distillation of 30-years of loudspeaker enclosure design, executed in an elegant and understated design.

Central to the Precision Series enclosure design is the philosophy that multiple materials should be used in enclosure design to create hybridised structures. Hybridised structural design is now seen across the spectrum where an engineering solution is sought to solve a design problem. The Precision Series represents an engineering solution to a product design problem, that of controlling structural born resonant energy within a loudspeaker enclosure to reduce the Q factor of the enclosure as much as possible.

2.1 - The Advantages of Hybridised Design

At the material level composite structures are formed. Carbon fibre composite is perhaps the best example of this. Here carbon fibres are added to a polymer such as epoxy resin, the carbon fibre provides strength and rigidity, whilst the polymer forms a matrix that allows the basic form of the material to be created. Taking this concept up from a material level to a whole structural level, it is possible to consider the benefits of using two or more materials with different strength, stiffness and damping properties to form what is commonly referred to as a hybridised structure.

2.2 - The Hybridised Design in the Precision Series Enclosure

The two constituent materials that form the Precision Series enclosure are aluminium and elemental birch plywood (see figure 1). If we consider the two materials in isolation for a moment, we could list aluminium's key strength as relatively high stiffness, whilst its weakness as very poor self-damping, that is to say when subject to resonant energy aluminium has one of the poorest abilities to dissipate the energy in the structure through heat versus resonance and sound. Whereas elemental birch ply exhibits a degree of stiffness, but its most desirable material property in this equation is the relatively excellent damping property that the material has compared with aluminium.

So we combine the two and what is the net result. Just as with composite materials, creating a hybridised structure using aluminium and wood, bestows superior stiffness within the structure provided by the aluminium, with vastly improved damping across the structure provided by the elemental birch ply.

Figure 1. The Precision Series Enclosure

2.3 - The Finer Detail of Design

The basic material selection is just the first step in the design of the Precision Series enclosure. But the real key to the success of high-end loudspeaker enclosure design is within the finer details of the design that exploit the properties of the materials used to maximum effect.

2.4 - Viscoelastic Membranes

Within all adjoining components of the Precision Series enclosure is a viscoelastic membrane. The function of this membrane is two-fold, first it ensures that all joints between enclosure components are air tight to achieve a fully sealed enclosure with only the exception of the ported area. Secondly, the viscoelastic membrane is as the name implies is created by a bonding agent that has an elastic property. The bonding agent has been selected for is elastic property so that an additional viscoelastic boundary is created to energy flow, a small reservoir if you like where energy is absorbed and in turn dissipated as heat rather than sound.

2.5 – 21st Century Loudspeaker Enclosure Design: High-Tensile Steel Ties

Another important optimisation of the Precision Series enclosure design is the use of high tensile steel ties that act as structural ties across both the horizontal and vertical axis of the loudspeaker enclosure (see figure 1). This design feature exploits the key advantage of aluminium within the enclosure design to maximum effect, that of stiffness. Threaded aluminium alloy ties are inserted into and bolted to the aluminium components used in the Precision Series enclosure. The threaded bars are then tied to create a high-tension clamping effect across the enclosure. This engineering solution is used in both the horizontal axis between the front baffle and rear baffle, but also within the vertical axis between the foot and the top of the loudspeaker enclosure.

2.6 – Multi-Axial Enclosure Optimisation: Tubular Transverse Stiffening & Damping

In the transverse axis thick walled tubes are added to the structure at optimised points within the plywood enclosure wall to stiffen and damp the enclosure (see figure 1). Finite Element Analysis has been used to inform the location of these tubes to ensure that their effect is maximised.

2.7 - A Moments Pause: Why tie and damp the structure in this way?

The effect of using ties within the Precision Series means that hundreds of kilograms of pressure can be exerted on all the surfaces of the Precision Series enclosure. It is a commonly understood principle of engineering that tying structures in this way creates strength and stiffness, architecture is the best example of this. But by exerting pressure across the surfaces of the enclosure you also improve the damping characteristics of the enclosure, imparting stiffness across the birch plywood panels from the aluminium and simultaneously improving the energy transmission from the aluminium structures into the birch plywood where the energy is damped through heat rather than the sonic ringing of the aluminium.

Both of these enclosure construction methods are taken directly from those methods used in the construction of reference class products in the Geometry Series. Taking the Eminence as an example, the same tie and brace methods and viscoelastic membranes are used in this design for the exact same effect.

Mutual Self Damping:
Aerospace Engineering Materials

> ***damp·ing***
> ***noun*** *Physics.*
> ***1.*** *a decreasing of the amplitude of an electrical or mechanical wave.*
> ***2.*** *an energy-absorbing mechanism or resistance circuit causing this decrease.*
> ***3.*** *a reduction in the amplitude of an oscillation or vibration as a result of energy being dissipated as heat.*

The concept of mutual self damping is central to any high performance engineering system, especially those where a high degree of control over the structures resonant behaviour is concerned. A rudimentary example would be the use of the fingers in stringed instruments to control the vibration in strings and so changing the sound the instrument makes.

Mutual self damping is based on the energy absorbing potential (damping ratio), of two quite different materials which are brought together. When the materials are disturbed from their static equilibrium, the resonant frequencies of each material act upon each other and reduce or stop completely, one and the others resonance – the mutually self damp one another.

The image in figure 2 shows one such example of a resonating glass, being damped by the finger. This is identical to the percussionist, damping the cymbal by grabbing it.

Wilson Benesch exploit mutual self damping in the Precision Series

Figure 2.

2.8 - The History of Mutual Self Damping in Wilson Benesch Designs

In 1994 Wilson Benesch announced the A.C.T. One Loudspeaker. At the time the design was radically different from anything that had been seen before in the high-end audio market.

Unlike the single material, rectilinear MDF box designs of the day, the A.C.T. One consisted of a curved carbon composite chassis. But the success of the design was based on the use of no fewer than five different materials, including hard wood, MDF, aluminium, steel and of course the A.C.T. composite.

3.0 - Drive Technology: The Dynamic Drive Unit

3.1 - Tactic 2.0 Drive Unit

The Tactic 2.0 drive unit is a hand built drive technology that has been designed and manufactured entirely in-house by Wilson Benesch (see figure 3). The development of Wilson Benesch drive technology is well documented in previous white papers and critical reviews. It has evolved iteratively through four generations to arrive at the Tactic 3.0 which is seen today in the company's flagship loudspeaker Eminence.

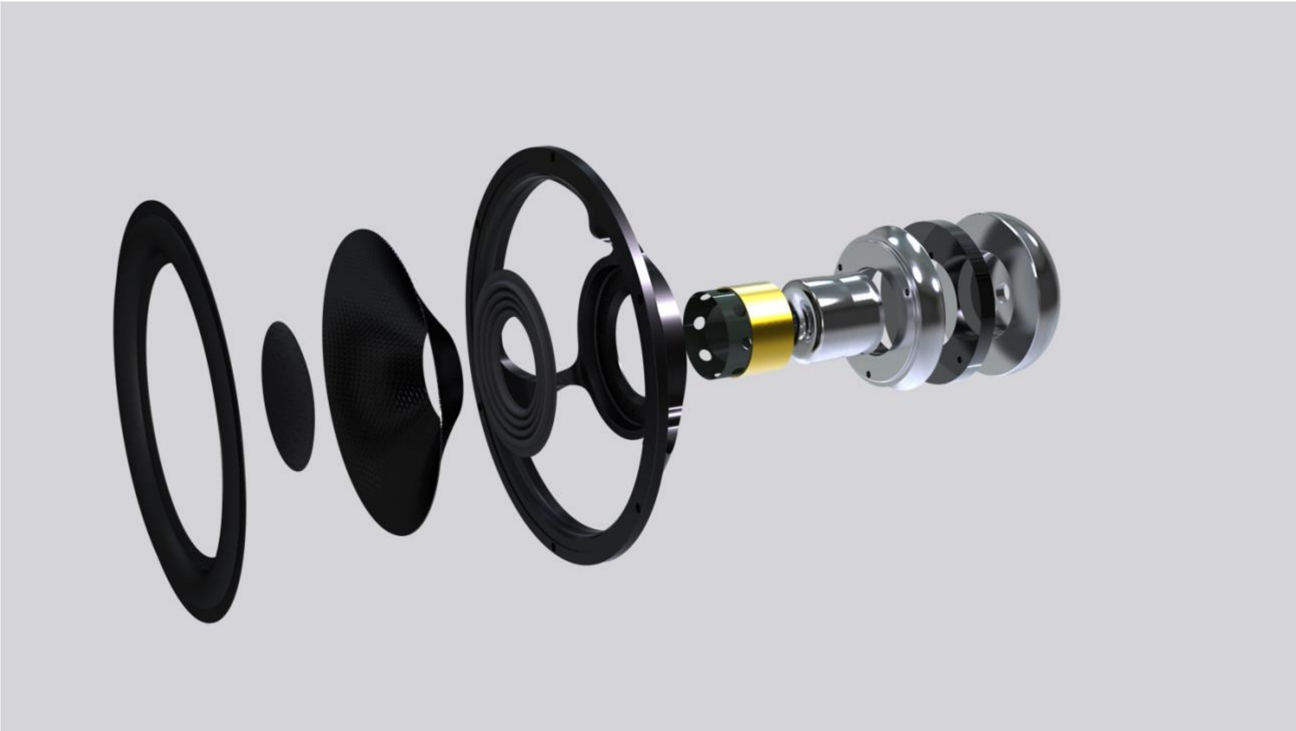


Figure 3. The Tactic 2.0 Drive Unit

The Tactic 2.0 drive unit seen in figure 3 and figure 5 is fitted by Wilson Benesch to all other loudspeakers in its reference line and it is now fitted within the loudspeakers in the Precision Series. Bespoke, hand-built drive technologies that include the midrange, bass and tweeters, plus loudspeaker enclosures all under roof in the United Kingdom, this is a considerable achievement and a strong unique selling point of the Precision Series line within the market place.

3.2 – The Tactic 2.0 – NdFeB Rare Earth Magnets & Optimising Magnetic Flux

When Wilson Benesch introduced the original multirole *Tactic Drive Unit* in 2001, it was the first drive unit in the market to utilise the magnetic power of NdFeB or rare earth magnet. Now more widely used in high end drive unit designs, but by no means industry standard owing to the very high cost of the material, NdFeB is the most powerful commercially available magnet available. The use of the strongest magnetic material available gives the drive unit designer the advantage of both power and control.

To extract maximum power from the NdFeB magnets, Wilson Benesch worked with the Sheffield University to conduct flux analysis of the drive unit motor design. A visual representation of a flux measurement across the Tactic 2.0 motor can be seen in figure 4 below. By analysing the flux across the geometry of the motor it was possible to optimise the adjacent steel front and back plates and so utilise as much magnetic flux and power from the magnet as possible.

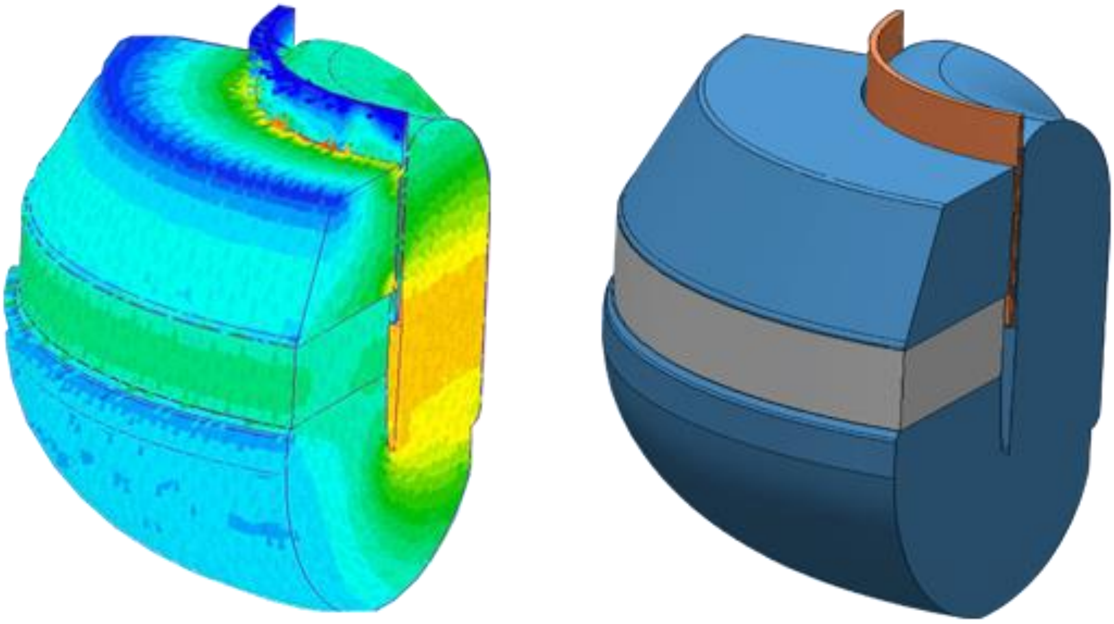


Figure 4. Measuring flux across the Tactic 2.0 motor

Within the motor geometry a small trough is created around the full periphery of the motor. Within this trough resides a voice coil. The voice coil is a circular tube structure with a copper coil wound around its outer surface, it is represented by the orange structure shown in figure 4 above. As current is applied through the coil from the amplifier, the voice coil becomes an electromagnet which is attracted to or repelled by the magnetic motor structure around the coil. By increasing the power of the magnetic motor structure, Wilson Benesch not only gain more power from the Tactic 2.0, but also more control over the voice coils movement.

The series of components that make this small part of the Precision Series loudspeakers is a great opportunity to illustrate how Wilson Benesch has structured its manufacturing and approach to design. The motor of the Tactic drive unit is a ground up design, made possible by three key factors,

- First investment in training and equipping a highly degree educated design team able to create 3D design within State-of-the-Art CAD/CAM computer packages
- Second the investment into and research and development of manufacturing technology capable of creating components realised by this design team. In this instance a CNC-machine. Just one of a fleet that now operate 7-days a week in the Wilson Benesch factory.
- Third the development of collaborative partnerships with centres of excellence, engineering institutions and Universities such as Sheffield University that allows Wilson Benesch to work collaboratively on R&D and access the very latest tools to analyse and assess R&D outcomes. Wilson Benesch now has a network of links to professors, engineers and doctors within a variety of fields that have been developed through the unique way in which the company has conducted its R&D projects. In 2019 at the time of writing, Wilson Benesch has won seven separate Government grants under a competitive application process. This has provided the company with over £1-million in public funding that has in turn been matched by the company to conduct R&D into innovative new technologies.

Figure 5, the Tactic 2.0 motor and basket

3.3 – The Tactic 2.0 in Cross Section

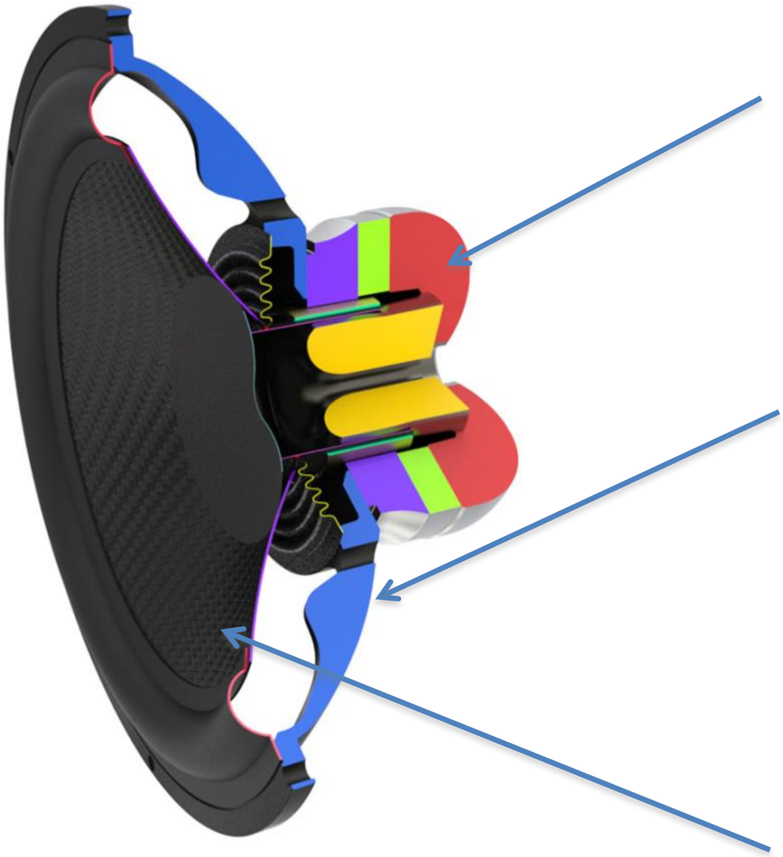


Figure 6, The Tactic 2.0 Drive Unit in cross-section

The curvaceous motor structure is manufactured in house on high precision CNC machines. Through collaboration with the Sheffield Hallam University, Wilson Benesch have been able to perform complex flux analysis across the structure. Every line of flux is fully optimised to extract the maximum power from the magnet. A film has been produced on the manufacture of the motor parts which can be viewed on Wilson Benesch TV

High pressure die cast basket delivers the ultimate window for energy to exit the rear surface of the diaphragm. Its reductive, streamline geometry affords the design a lot of stiffness, whilst minimizing any obstruction to airflow in the highly pressurized zone to the rear of the drive unit.

Isotactic Polypropylene was invented by Professor Ward of Leeds University. Wilson Benesch collaborated with the professor to introduce this superb material to the audio industry. It was the first commercial product to be realised from his invention.

An interview with Professor Ward, can be viewed on Wilson Benesch TV.

3.4 – Isotactic Polypropylene

The timbre, quality and clarity of the sound produced has a direct relationship to the material used to create the sound. Underpinning the Wilson Benesch design philosophy is a consistent reference to science; in engineering and the application of the basic physical laws that govern the universe. Since the foundation of the company in 1989, advanced materials technology our R&D programmes have consistently revolved around the application of materials science to solve engineering problems to create better product design.

Figure 7, the Isotactic Polypropylene Drive Unit Diaphragm

When the voice coil is subjected current from the amplifier, the coil moves electromagnetically and in turn moves the drive unit diaphragm in and out. As the diaphragm moves the air in front of the drive unit it creates sound waves at different frequencies that reproduce a musical piece. To recreate music with high-fidelity, the drive unit cone must be under control at all times by the magnetic motor and critically the diaphragm must be able to retain its principle form or shape when under immense pressure that is created by the pistonic movements of the cone.

In this regard isotactic polypropylene seen above in figure 7, has a unique set of material properties that make it the ideal choice for a drive unit diaphragm. Isotactic polypropylene is relatively stiff and therefore able to faithfully maintain its form to reproduce the full range of audio frequencies required. However, isotactic polypropylene also exhibits excellent damping across its structure, that is to say that the material is able to dissipate energy within its structure as heat rather than through structural resonance. This is a critical point.

There are stiffer materials than can be used for drive unit diaphragms. However each material choice presents a different set of problems. With stiffer materials the primary issue is the lack of damping within the material itself. When the material is unable to damp itself it starts to resonate and produce the sibilant high frequency distortions that commonly afflict such designs.

Wilson Benesch consistently work on R&D within its drive unit development programmes. As early as 1995, the company undertook R&D into carbon fibre diaphragms made from a carbon fibre / epoxy matrix. However within the midrange and bass drive units this material has, to date, been rejected because the stiffness versus damping of this material does not suit this application. Those interested in the use of carbon fibre in the Wilson Benesch Torus Infrasonic Generator can refer to the white paper on that product. In summary, the Torus is an example of where Wilson Benesch have developed a unique carbon fibre – polyethylene tetrafluoride fabric to synthesise an 18” diaphragm for the Torus. Here the requirements of the design are very different and thus the mechanical load of the cone is also very different from that of the drive unit diaphragm in the Tactic 2.0.

Isotactic polypropylene was developed by Professor Ian Ward. Isotactic literally means, “of equal inclination” and refers to the repeating, regularly spaced methyl group on the backbone of the chain within isotactic polypropylene chemical structure allowing the macromolecules to coil into a helical shape. It is this chemical property that makes isotactic polypropylene the most suitable choice for a high-end drive unit design. Watch Professor Ian Ward discuss isoactic polypropylene in this interview conducted with Design Director Craig Milnes on Wilson Benesch TV.

4.0 – Drive Technology: The Tweeter

The Leonardo tweeter belongs within the second generation of tweeter developments made by Wilson Benesch. Leonardo and its close relative the Fibonacci Tweeter that features in the flagship Eminence loudspeaker are decedents of the companies Semisphere Tweeter. The Semisphere was developed over almost a decade long R&D project that built upon knowledge and experience gained by working with some of the best tweeters in the world at the time, namely the Piezo Sphere Supertweeter that featured in the Wilson Benesch Wide Bandwidth Series.

The Leonardo Tweeter builds upon the technologies introduced by Semisphere, adding an innovative decoupled design (figure 8) and a geometrically optimised waveguide faceplate (figure 9) to elevate the performance of the new generation of Wilson Benesch tweeters. The Leonardo and Fibonacci tweeter faceplates mimic and exploit the benefits of natural geometry that has evolved over millennia.

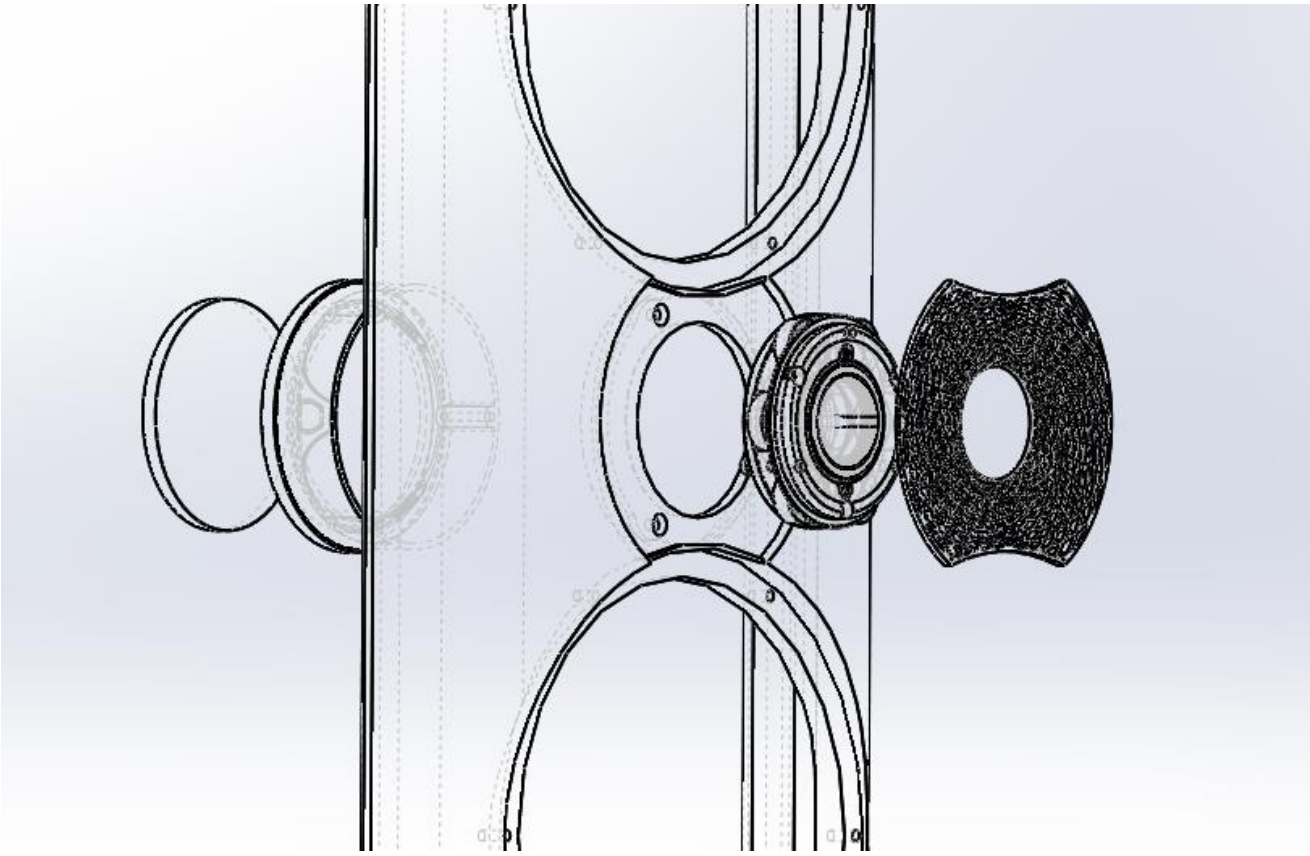


Figure 8: The Leonardo front faceplate is decoupled from the rear motor and chassis

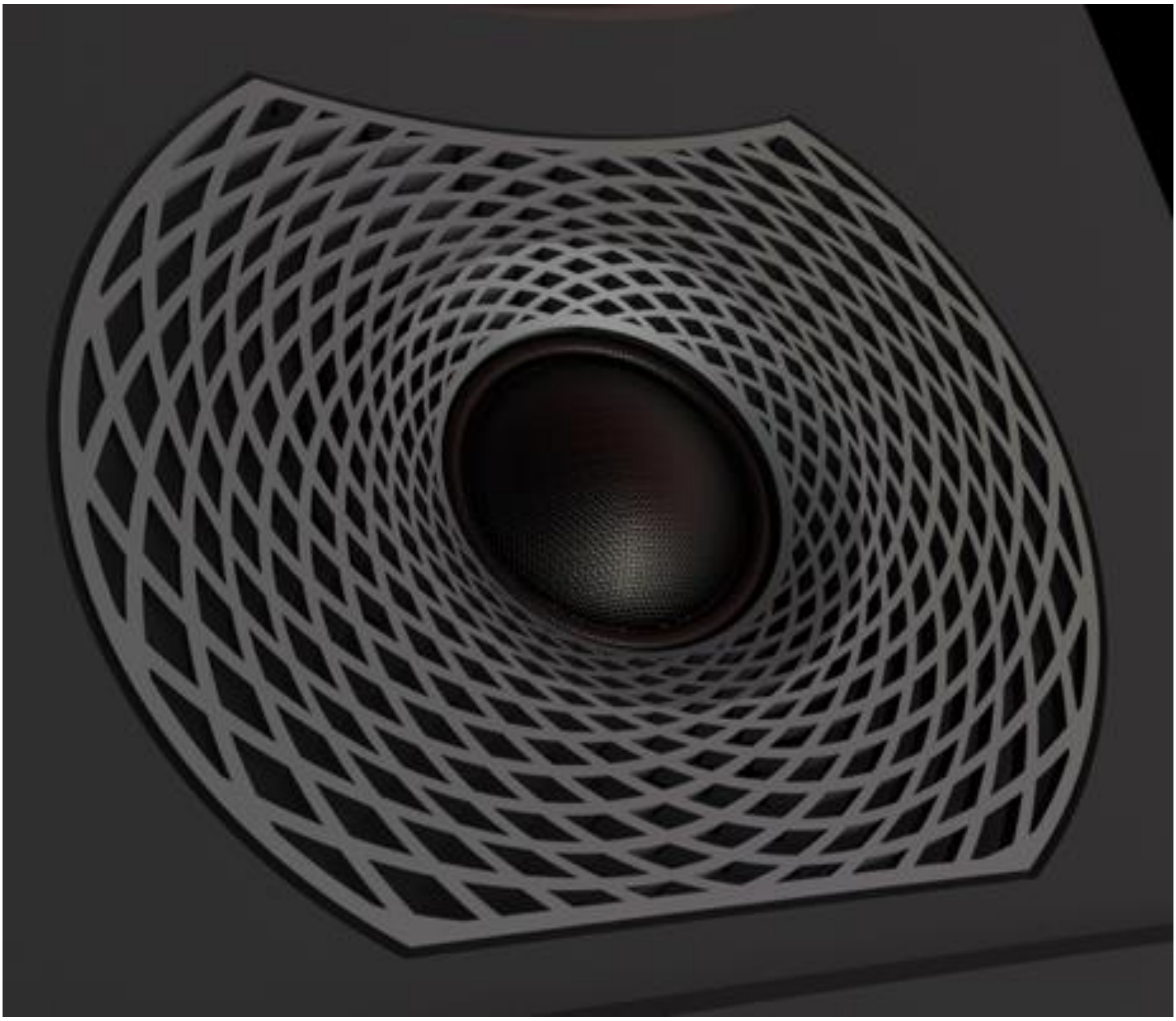


Figure 9: The Leonardo waveguide Faceplate

4.2 – The Leonardo Tweeter Faceplate

Sound waves interact with surfaces within a given space, thus it follows and is commonly understood that the structures adjacent to a loudspeakers tweeter dome interact with the sound produced by a tweeter. During the development of Semisphere and the subsequent development of this second-generation of tweeters, Wilson Benesch tested and analysed the critical function a tweeter faceplace plays in the constructive and destructive interactions the faceplate has in the sound waves propagated from the dome of the tweeter. The outcome has been two new tweeters, named Leonardo in the Precision Series and Fibonacci in the Geometry Series which pay homage to the Italian 12th-century mathematician.

One of the major challenges in the design of a tweeter faceplates is the output response cancellation effects created by the tweeter faceplate. The Leonardo Tweeter features a simple second-order crossover operating from 5,000KHz to 20,000KHz where it it's response is flat. At 20KHz the wavelength of a sound is 17mm, at 10KHz the wavelength of sound is 34mm. The second generation tweeter faceplate has been designed to minimise both the cancellation effects of the faceplate and the additive effects of the faceplate, affording the new tweeters a flatter frequency response.

The highly optimised faceplate structure has been made possible through very recent advances in manufacturing technology, known as additive manufacturing. Additive manufacturing is set to transform the manufacture of all products and Wilson Benesch has been involved in developments in this field at the outset thanks to its collaborations with Sheffield University and the Advanced Manufacturing Research Centre (AMRC). Wilson Benesch added additive manufacturing systems to the company's manufacturing capability in 2017. Since then a broad range of applications have been realised.

Wilson Benesch already manufactures many components in both metal and carbon reinforced polymer. However it is the design process behind this work that has been critical to the development of these structures, essentially mimicking nature. The lattice structure is as you would expect a hybrid. The principle "seen component" is built from a carbon reinforced polymer that is extremely low mass and extremely high in damping. Significantly this structure is completely decoupled from the main baffle by the sub structure that is visible through the lattice. The resulting flat response of the Leonardo tweeter owes much to this perfectly adapted system that represents the State-of-The-Art in tweeter face plate design. This type of development would have been impossible until only very recently. It's success owes much to the innovation of the original Semisphere. It is these small steps that Wilson Benesch will continue to take as an innovator and advanced materials manufacturer that will enable the small but significant accumulative benefits of on-going research and development.

4.3 - The Leonardo Tweeter – NdFeB Rare Earth Magnets & Optimising Magnetic Flux

The motor at the heart of the Leonardo Tweeter is identical to that used in the Geometry Series Semisphere Tweeter. The motor is a highly evolved structure that seeks to optimise the tweeter design both from a geometric perspective and from a material perspective.

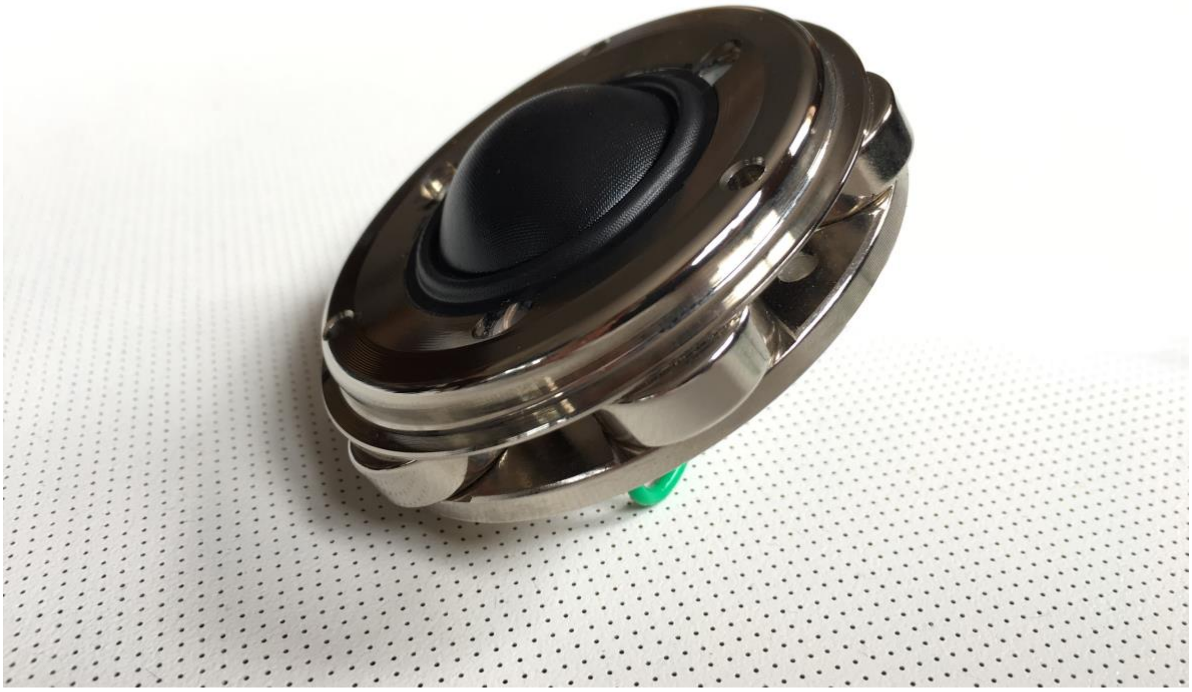
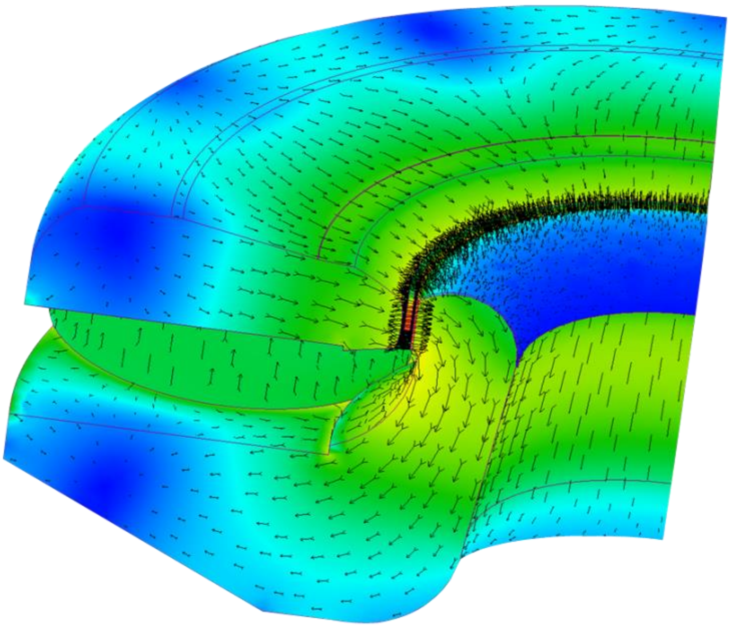


Figure 10: The Leonardo Motor Structure

The first thing to observe about the tweeter motor is its physical structure. Looking at figure 10 above the open ring structure can be observed. Six NdFeB rare earth magnets sit around the periphery of this ring, held in position by a front and rear motor plate. Just as with the Tactic 2.0 Drive Unit, the motor of the tweeter was analysed by the Sheffield University to optimise the magnetic flux across the structure.



This design delivers maximum magnet flux, whilst also addressing another critical concern within tweeter designs which is cooling.

When a magnetic structure heats up, the performance of the magnet reduces. During use a tweeter generates a lot of heat and therefore to keep the structure cool, Wilson Benesch designed the tweeter motor to have an open architecture that allows optimal cooling during use. This ensures the tweeter is always operating with maximum power and control over the dome.