Nature-Inspired Surfaces and Engineering Applications Using COMSOL Multiphysics®

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Abstract

Nature evolved over millions of years to produce remarkable surfaces and shapes. Nature inspired, equation based mathematical surfaces were developed over many centuries. Sample inspiring and complex mathematical Surfaces are shown in figure 1. These intriguing shapes and surfaces based applications are confined within the mathematical and simulation domain for centuries, due to limitation in conventional manufacturing methods, cost effectiveness and practical feasibility. Recent developments in 3D printing and CAE, empowers to make these complex shapes a practical reality and hence the renewed interest. In this paper various nature inspired equation based mathematical surface are developed in COMSOL® software, leveraging parametric surface feature. A list of surface from Archimedean spiral to Wallis's Conical Edge was developed. These surfaces were used to build engineering products. Select surfaces, governing mathematical equation, CAD model and Engineering product details are detailed.
Equation based Surface model and applications:
The CAD model building capabilities of COMSOL® software is leveraged for equation based surface model and product development. We have developed parametric COMSOL® software models of more than 25 surfaces. However, the details of Fresnel's Wave, Klein, and Gyroid surface and applications will be detailed.
Fresnel's wave surface is a quartic surface describing the propagation of light in an optically biaxial crystal. The wave surface is created using parametric surface feature of COMSOL Multiphysics® software. This wave surface is then converted into 3D print models with patterns of nature inspired structures as shown in figure 2 for multitude of Fresnel wave organic structure based applications.
Klein surface is a mathematical surface on which the notion of angle between two tangent vectors at a given point and the angle between two intersecting curves on the surface are well defined. The boundary of a compact klein surface consists of finitely many connected components, each of which is homeomorphic to a circle. These components are called the ovals of klein surface. Figure 3 shows architectural application derived from Klein surface. The aesthetic design of this model is designed and it's shape is used to produce stiff structures inspired from nature. The generated structures are created controlled by generative algorithms. The given model is an example of mathematical surface derived from klein surface. This complex model is used to construct nature inspired structure of a stadium.
The gyroid surfaces are developed using parametric surface models with trigonometric equations. A gyroid surface is an infinitely connected triply periodic minimal surface. Figure 4 shows sample gyroid surfaces and unit cell of various shapes and surfaces. Gyroid

structures have photonic band gaps for novel electromagnetic zero transmission, 100% transmission type applications. The organic patterned structures of gyroid surface are stiffer and lightweight for cellular solid based materials and structures.

Conclusions

The parametric surface feature of COMSOL® software was leveraged for developing equation based mathematical surfaces into CAD models and innovative 3D printable engineering Structures.

Figures used in the abstract

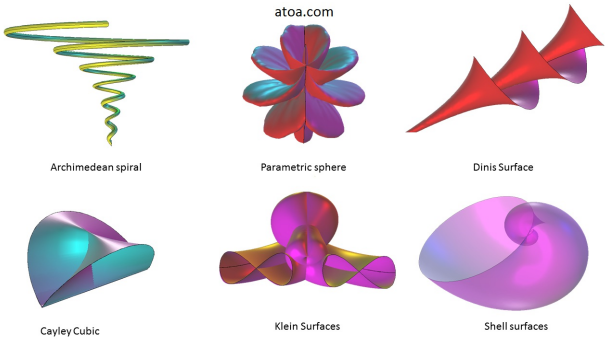

Figure 1: Nature inspired Equation based Surfaces.

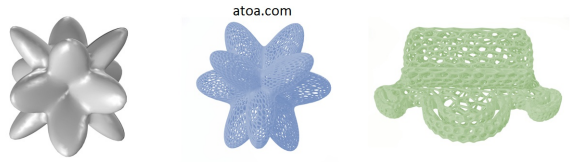

Figure 2: Fresnel Wave surface and Organic Structure.

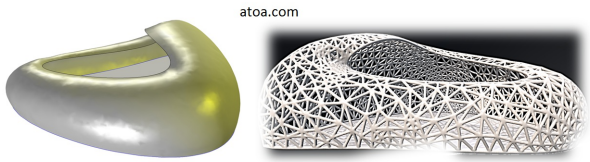

Figure 3: Klein Surfaces and inspired Architectural form.

Figure 4: Gyroid type surfaces and Applications.