# 软件介绍及发射药理论基础
# 摘 要

本设计从理论角度出发，为提高发射药的能量利用率，改变药型，提高燃烧渐增性，以几何燃烧定律和增材制造技术为理论依据，利用 3D 打印一体化成模以及逐层增材的特点，设计了立方空槽柱形发射药和多列环形空槽管形发射药，并在后者基础上对结构上做了两种修改设计；对四种药型随时间变化的燃烧规律分析并设计公式。统一药型尺寸，利用 UG 对不同节点构型，测量燃烧面以验证公式；比较相同尺寸各药型的装药量；引入增面值定义，比较各药型增面值变化；引入相对燃气生成量定义，比较各药型的相对燃气生成量变化；用 UG 对 155 口径的 19 孔发射药建模，从增面值变化和相对燃气生成量变化进行分析，并以相对燃烧层厚度为参照量同多列环形空槽管形发射药进行比较。再以燃烧时间 t 为参照比较剩余四种药的增面值变化，结果表明：

（1）利用推导的四种药型的燃面计算公式，初步计算燃面变化，结果证明所设计药型设计合理。

（2）相同尺寸四种发射药装药量最小为多列环形空槽分裂杆形发射药，以此为基准，新型多列环形空槽管形发射药的装药量是其 1.02 倍，多列环形空槽管形发射药的装药量是其 1.05 倍，最高的是立方空槽柱形发射药，装药量是其 1.21 倍。

（3）以相对燃烧层厚度为参考同多列环形空槽管形发射药比较，19 孔发射药增面值最高仅有 2.14，无突增，多列环形空槽管形发射药燃烧增面值最高为 10.35。

（4）在相对燃气生成量来看，立方空槽柱形发射药燃烧面积后期达到初始值的 4 倍以上，四种药型设计中最低为多列环形空槽管形发射药，燃烧面积为初始值 2.5 倍以上，但仍然优于燃烧面积不及初始值 2.1 倍的十九孔发射药。

（5）多列环形空槽管形发射药无明显缺点，各项数据处于中间位置；新型多列环形空槽管形发射药燃烧速度快，燃面突增过程短，仅为多列环形空槽管形发射药的一半，相对的燃烧面积增长优于前者；多列环形空槽分裂杆形发射药第三列空槽开始燃烧时燃面突增为四种发射药里最剧烈；立方空槽柱形发射药燃烧速度略慢，比其余发射药多一个燃烧面突增阶段，增面燃烧持续时间长。

**关键词**：发射药；增面值；3D 打印；药型；燃烧渐增性

# Abstract

From the theoretical point of view, in order to improve the energy utilization rate, change the propellant type, and improve the combustion increasement, based on the geometric combustion law and additive manufacturing technology, using the characteristics of 3D printing integrated molding and layer by layer additive, the square hole cubic hollow groove cylindrical propellant and multi column annular hollow groove tubular propellant are designed, and on the basis of the latter, on the basis of the structure Two modified designs are made, and the combustion laws of four types of propellant with time are analyzed and the formulas are designed. Unify the grain size, use UG for different node configurations, measure the combustion surface to verify the formula; compare the charge amount of each grain with the same size; introduce the definition of increased face value, compare the change of increased face value of each grain; introduce the definition of relative gas generation, compare the change of relative gas generation of each grain; use UG for modeling 19 hole propellant with 155 caliber, from the change of increased face value and relative gas generation The change of volume is analyzed, and the relative thickness of combustion layer is taken as reference to compare with the Multi row annular hollow channel tubular propellant.Then, the change of the added value of the remaining four propellants was compared with the combustion time t.The results show that:

(1) By using the formula of four types of propellant, the change of the burning surface is calculated preliminarily. The results show that the design of the propellant is reasonable.

(2) The minimum charge quantity of four kinds of propellants with the same size is the split rod shaped propellants with multiple annular slots. On this basis, the charge quantity of the new type of tubular propellants with multiple annular slots is 1.02 times of that of that, the charge quantity of the tubular propellants with multiple annular slots is 1.05 times of that of that, and the maximum charge quantity is the cylindrical propellants with square hole vertical square slots, and the charge quantity is 1.21 times of that of that.

(3) Compared with the whole propellant, the maximum increased value of 19 hole propellant is only 2.14, no sudden increase, and the maximum increased value of multi row annular hollow tube propellant is 10.35.

(4)In terms of relative gas production, the combustion area of square hole cubic hollow slot cylindrical propellant reaches more than 4 times of the initial value in the later stage, and the lowest of the four propellant designs is multi column annular hollow slot tubular propellant, with the combustion area more than 2.5 times of the initial value, but still better than the 19 hole propellant with the combustion area less than 2.1 times of the initial value.

(5)There are no obvious disadvantages of the multi row annular hollow tube propellant, and the data are in the middle position. The new multi row annular hollow tube propellant has fast combustion speed and short process of sudden increase of combustion surface, which is only half of that of the multi row annular hollow tube propellant, and the relative increase of combustion area is better than the former. The third row of multi row annular hollow split rod propellant has four kinds of sudden increase of combustion surface at the beginning of combustion The combustion rate of square hole cubic hollow slot cylindrical propellant is a little slower than that of other propellants, and the combustion duration is longer.

Key words： Propellant; increased face value; 3D printing; propellant type; combustion increasing