3D 立体显示技术简介

1. 3D 立体显示技术的原理

3D 立体显示技术主要是产生两幅不同角度观看对象的图像，两幅图像分别要让人眼的两只眼睛独立看到，两只眼睛看到的两幅图像通过大脑合成为立体图像。两幅图像通过显示设备如显示器或投影同时显示出来或快速间隔显示出来，通过设备将两幅图像区别开来。一种方法是在显示器上为两眼区别开来，一种是在人的眼前区别开来，如图 1 所示。对应前者，可以通过视差光栅实现，让两幅图像分别让两眼看到，该类显示屏一般比较小，而且对观看者和显示器的相对位置要求比较严格。但该方法的好处是裸眼实现，观看者不需要戴眼镜。另一种是在观察者的眼前进行区别，有电子快门式、偏光式和红蓝等形式。

电子快门式通过眼镜中的电子控制快门快速轮流切换，分别让两眼看到两个角度的图像，这也需要显示器或投影仪的同步才行，显示器或投影仪轮流播放两只眼的图像，同时通过和眼镜通信，让眼镜同步控制左眼该看到的图像让左眼看，右眼关闭，让右眼观看的图像让右眼看，左眼关闭。开关频率符合人眼的习惯，这样就实现了两眼分别看到不同图像。电子快门式因为左右眼图像交替播放，因此需要显卡的支持，NVIDIA 是最常见的 3D 显卡。

偏光式眼镜和偏光式显示屏配合，同步播出两幅图像，眼镜两个镜片的偏光角度不同， 从而分别过滤掉另一幅图像，这样就实现了两眼观看不同图像。偏光式眼镜也可以和偏光投影设备相结合投影到屏幕，这时需要两个投影仪，投出光的偏振角不同的图像， 而且要同步，并且对显示屏要求比较高。

红蓝眼镜不需要和特殊要求的硬件设备相匹配，常规任何播放设备都行，如显示器、投影仪、彩色印刷品等。俗称红蓝，其实是红青，青色是蓝色和绿色的混合。其原理是将观察对象的两幅图处理成红青两种色系，任何可见光都是红绿蓝三色组成的，这样一幅没有蓝色和绿色，一幅没有红色，红色镜片过滤掉非红颜色，但红色显示成白色，青色镜片让蓝绿色通过，两幅图像分别由红蓝眼镜片过滤掉对方的图像，使人眼只能看到一幅图像，这样就产生了立体感，如图 2 所示。由于红色通过红色镜片过滤后为白色，被青色镜片过滤后为黑色，因此红色会失真为黑色。依据颜色互补原理，还有红绿模式、棕蓝、粉绿、绿粉模式等。

还有一种形式是两幅图像并排排列，通过适合人眼工学参数的遮挡等方法实现左眼只看到右面的图像，右眼只看到左面的图像，从而实现 3D 立体效果。

此外，还有眼镜片上分布众多小棱镜进行颜色区分从而实现两眼看到不同图像的方法，以及全息技术等。

2. 3D 立体显示技术在铸造中的应用

在铸造模拟仿真中有造型文件、有限差分、有限元网格文件、计算结果文件，包括：温度场、流场、应力场、应变场、位移场、微观组织，还有铸造缺陷，如缩孔缩松、裂纹等。由于铸件形状复杂，因此传统观察手段比较麻烦，对于不熟悉的人来说，难度很大，往往借助于反复旋转、透视、切片、消隐、放大

等功能。因此 3D 立体显示技术非常有用，可以快速帮助观察者看清铸件的形状，分析结果的分布情况，通过转动，能够更快了解结果的全貌。也可以观察铸件、冷铁、补贴、浇注系统、保温冒口等的相对位置关系。还可以观察缩孔缩松等缺陷的位置。

美国 CEI 公司的 Ensight 是一种数值模拟结果 3D 立体显示后处理软件。作者在 Ensight 基础上二次开发，实现了铸件铸造数值模拟结果的显示。本书整理了作者十几年来的铸件数值模拟算例并进行了 3D 红蓝立体显示处理。

注意：有些 3D 立体图可能需要适应几秒才能更好地看出立体效果。

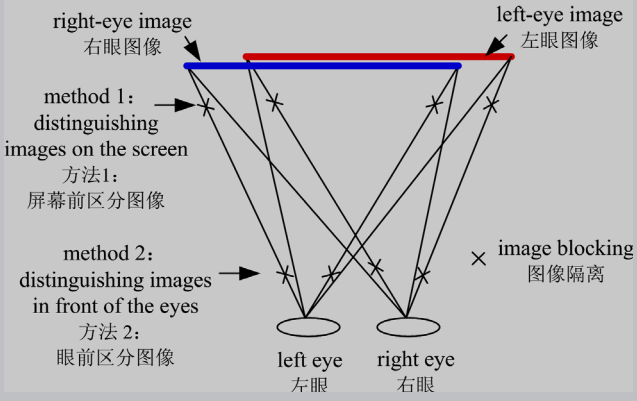
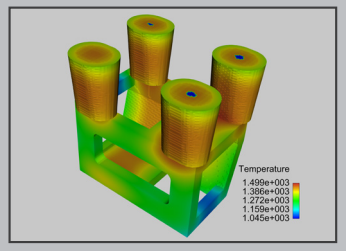
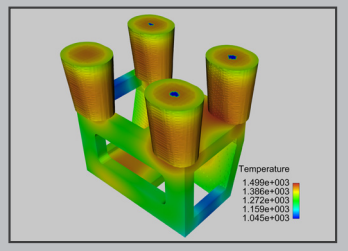


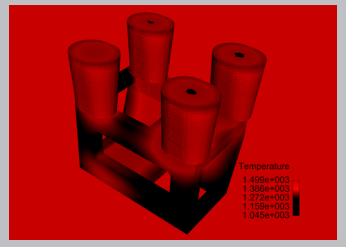
图 1　3D 立体显示原理
Fig.1　The principle of 3D stereo imaging



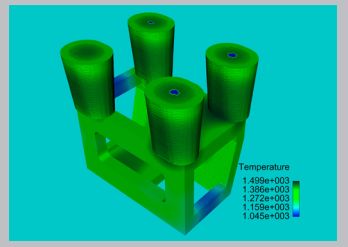
(a) 左眼观察图 left image



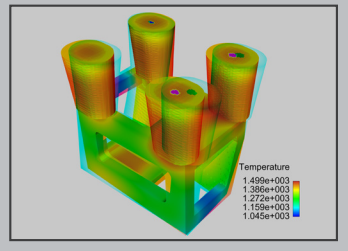
(b) 右眼观察图 right image



(c) 左眼图像红色过滤
left image after red infiltration



(d) 右眼图像蓝色过滤
right image after cyan infiltration



(e) 合成 3D 立体红蓝图像
synthetic 3D red-cyan image

图 2　基于红蓝方式的 3D 显示图像处理原理
Fig.2　Generation process of a 3D red-cyan image

3D Stereoscopic Visualization Technology

1. Stereoscopic Principles

3D stereoscopic display technology is mainly based on the principle of binocular parallax. Firstly, two images with parallax information are acquired, then technical means are utilized to make sure that the two images are seen by the corresponding eyes respectively, and stereo effect is perceived by the observer when the information received by two eyes is transmitted to brain. Two images displayed on the monitor or projector screen simultaneously or in a very short interval are distinguished by devices. One method of distinguishing two images is to separate them on the monitor, the other one is to separate them in front of the eyes, as shown in Fig. 1. The former method can be realized by parallax raster, which lets the two eyes receive two different images respectively. The monitor in this method is relatively small, and strict demand is required on the relative position between the observer and monitor, however, the advantage of this method is that it can bring about stereo effect to the observer without wearing 3D glasses, that is, naked-eye 3D effect is realized. In the latter method, two images are distinguished in front of the observer using 3D glasses, which has varieties of forms, such as electronic shutter type, polarizing type, red-blue type and so on.

The electronic shutter glasses let the two eyes see images in two directions through the fast switch of images controlled by electronic shutter in the glasses, meanwhile, synchronous switch of monitor or projector is required. The monitor or projector displays the left and right images in turns and keeps in communication with the glasses, as a result, when the device is displaying the left image, the left glass is switched on while the right one is switched off; when the device is displaying the right image, the right glass is switched on while the left one is off. The switching frequency is generally higher than 120Hz, which guarantees that the two eyes receive two different images.

Due to the alternating display of the left and right images, the electronic shutter glasses need the support of 3D graphics cards, such as NVIDIA.

The polarizing glasses work with the polarizing monitor, which displays two images polarizing in different directions simultaneously. Polarizing angles of the two pieces of glasses are different, in this way, only the image corresponding to the specific piece of glasses can be received, as a result, two eyes see two different images. 3D stereoscopic display can also be realized through the co-work of polarizing glasses and polarizing projectors, in this condition, two projectors are required to project two parallax images overlapping on the screen, whose polarization properties must be guaranteed.

It is not necessary for the red-blue glasses to function with the auxiliary of hardware which has special performance, conventional media such as monitors, projectors, and even color printings can bring about 3D stereo effect with the help of glasses. The technology commonly called as red-blue display is actually a way of red-cyan display, the color of cyan is a combination of blue and

green. The principle of red-blue glasses is that the left and right parallax images are displayed complementarily in red and cyan. In the RGB mode, any kind of color consists of red, green and blue. The observer's left eye can only receive red images through the red-light filter on the left side, as there is only the red component reserved; while on the right side, only cyan images can be seen by the observer's right eye as a result of the filtration of cyan light. By this way, different parallax images can be received by two eyes respectively and stereo visualization is realized. Based on the same color filtration theory, the genearation of a 3D stereo red-cyan image is the comination of the red-filtrated left image and the cyan-filtrated right image, as shown in Fig. 2. Incorrect color may occur in 3D stereo images when they are seen through the red-blue glasses. There are also 3D glasses based on other kinds of color combination, such as red-green, brown-green, pink-green, green-pink glasses and so on.

Another method of realizing 3D stereo effect is to place two images side by side and utilize the occlusion according with human-eyes ergonomic parameters in order to let the left eye see the right image while the right eye sees the left image.

Besides, there are other ways to obtain 3D effect, for instance, assigning lots of small prisms scattered on the glasses to distinguish colors so as to let two eyes receive different images; and holographic technique can be applied in 3D stereoscopic display as well.

2. The Application of 3D Stereoscopic in Castings

Castings are usually of complicated shape, which is the reason of how casting method is applied to form the parts. Therefore, the 3D stereo visualization is of great significance in the modeling and simulation of castings. Here, this technology is used to cover all the pre- and post- processing, including the STL surface meshes, finite difference and finite element meshes, various results, such as mold filling, temperature fields, stress and strain fields, displacement field, and the defects such as shrinkage and porosity, hot tearing tendency. All of the results are converted into red-cyan type 3D images, which can be viewed by red-cyan cardboard glasses attached in the book. The castings covers almost the often used casting alloys, such steel, cast iron, aluminum alloys, and all kinds of casting methods such as sand casting, investment casting and die casting. The results include mold filling, solidification, cooling in the mold and also heat treatment. By the aid of 3D stereoscopy, the results can be easily and efficiently viewed and analyzed by the viewers. Meanwhile, the electronic files of the photos and also animations of the mold filling process or the rotation of the results are burned into DVD. These electronic files can be watched by any traditional players such computer, notebook and TV set.

Ensight, developed by CEI, an American company, is software for 3D stereoscopic visualization of numerically simulated results. The authors develop the 3D stereoscopic visualization function for simulated results of castings based on Ensight. The case studies for castings performed by the authors in twenty years are treated into 3D stereoscopic effect and are presented in this album.

Notice: For some 3D stereo images you may watch them several seconds to feel the 3D stereo effect.

铸造模拟仿真案例
Numerical Simulation Case Studies of Castings

案例 01 铝合金缸体

某四缸铝合金缸体，采用低压铸造，底部充型，浇注系统有 5 对内浇口。从图（6—28 页）中可以看出液态金属从底部上充，首先充满浇注系统，然后金属液流分别向左右两侧缸体的轴承座部分自上而下充填，该部分低于浇注系统的入口，随后随着液流向两侧的充填，中间部分液面也在逐渐升高。在初始的一段时间 5 对内浇口独立充填对应部分，没有汇合。轴承座部分壁薄，且形状复杂，因此充填较困难，尤其是在中间两个缸筒对应的轴承座部位。而且在轴承座侧壁上充填时多处为结构的末端，因此要注意排气，否则容易出现气体引起的铸造缺陷。经历较长一段时间后两侧壁液面才达到中心部分液面。铸件中有很多水平或上下圆筒结构，水平圆筒多通过底部绕流充填远离浇口端，如视图右前方的部位，液流要绕过底部充填端部，因此充填也较慢。后期阶段充型比较平缓，液面高度基本水平。（6—28 页）

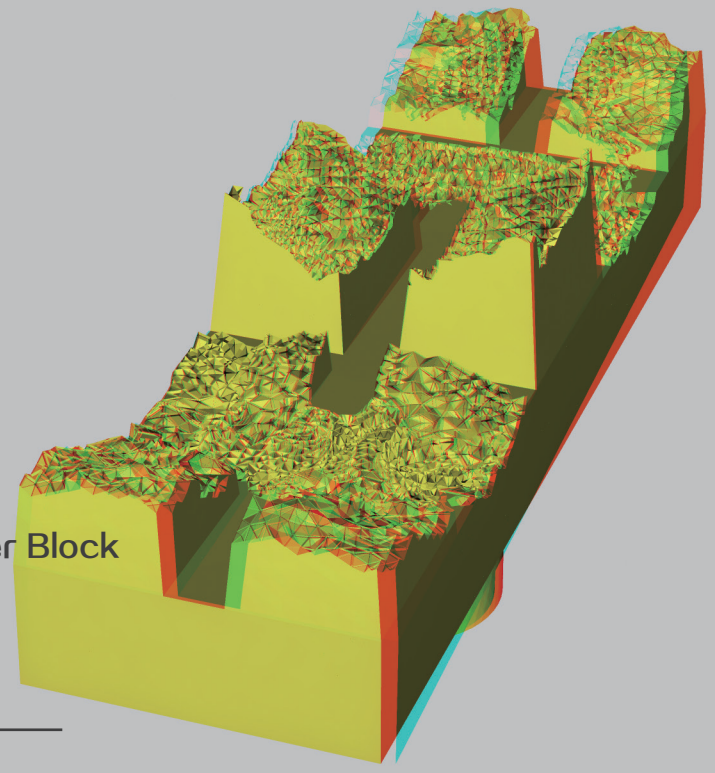
Case 01 Aluminum Cylinder Block

A 4-cylinder block, low pressure die casting, bottom filling, five pairs of ingates. It can be seen from the figures (Pages 6—28) that the melt fills the ingate system first, and then splits to fill the two lower sides of the walls which are lower than the ingates. The filling of each pairs of ingates is isolated at the beginning. The shape of the lower side walls are of complicated shape, the filling is relatively difficult. The middle is filled later than the two ends. The filling of the side walls is prone to entrap air and cause air related defects, so the ventilation should be paid attention. After the melt fills the cylinder part, the melt flow comes to keep steady. (Pages 6—28)

铝合金缸体
Case 01 Aluminum Cylinder Block

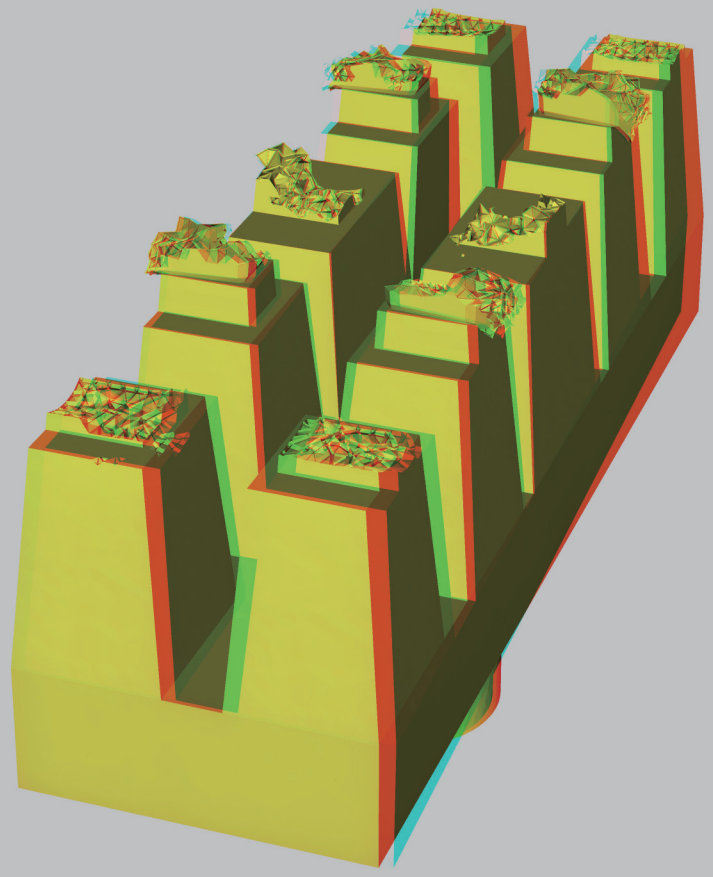
低压铸造，底注充型
Low pressure die casting, bottom filling

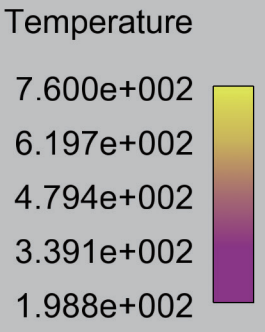
充型过程
Filling process

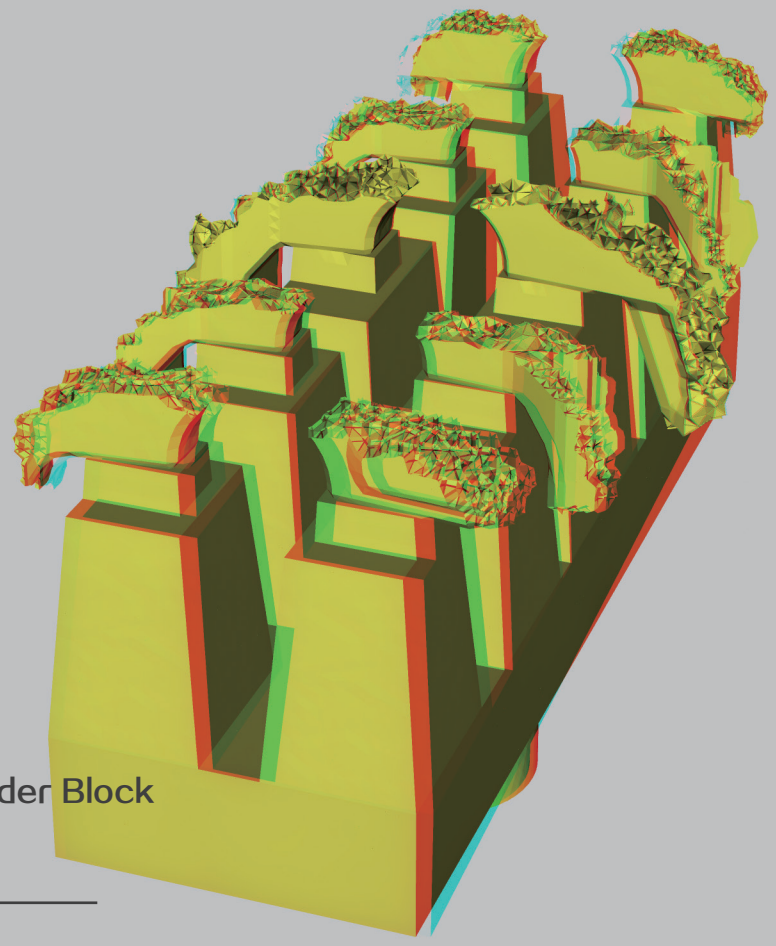


铝合金缸体
Case 01 Aluminum Cylinder Block

充型过程
Filling process







铝合金缸体

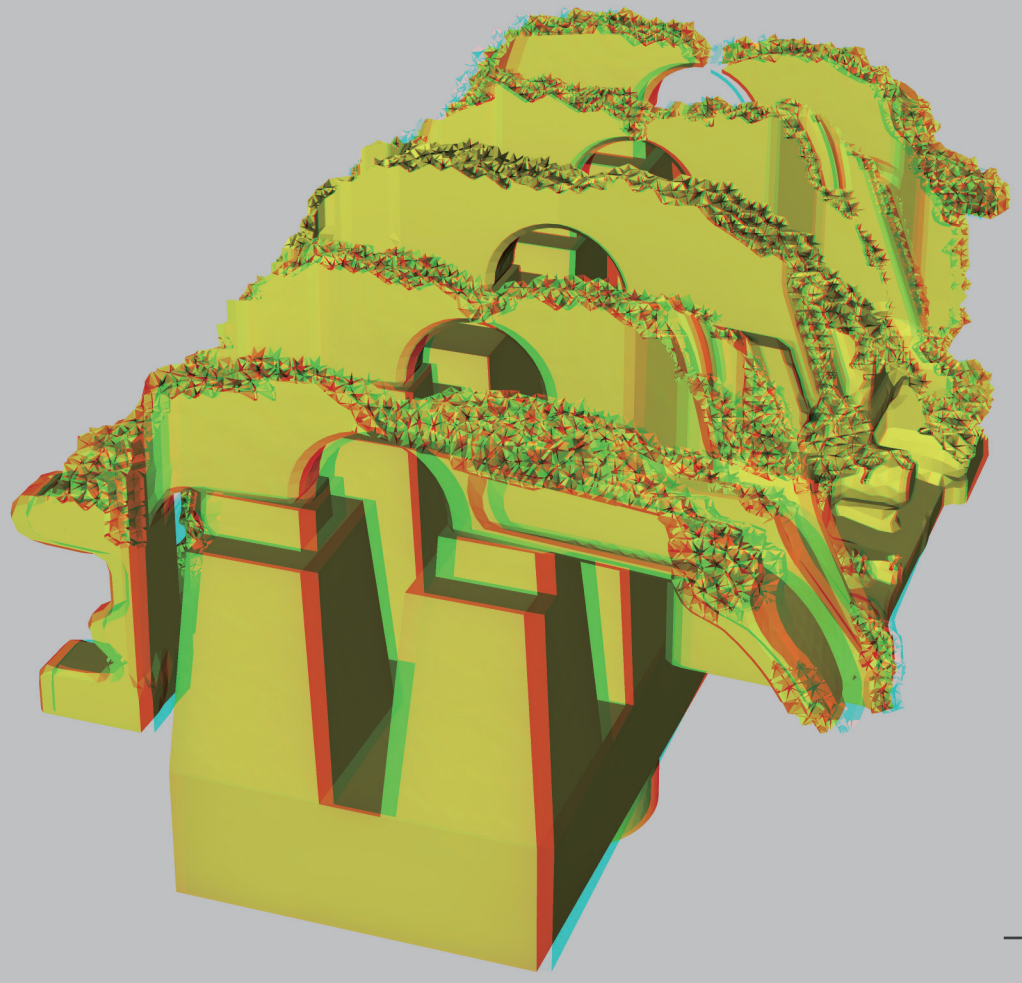
Case 01 Aluminum Cylinder Block

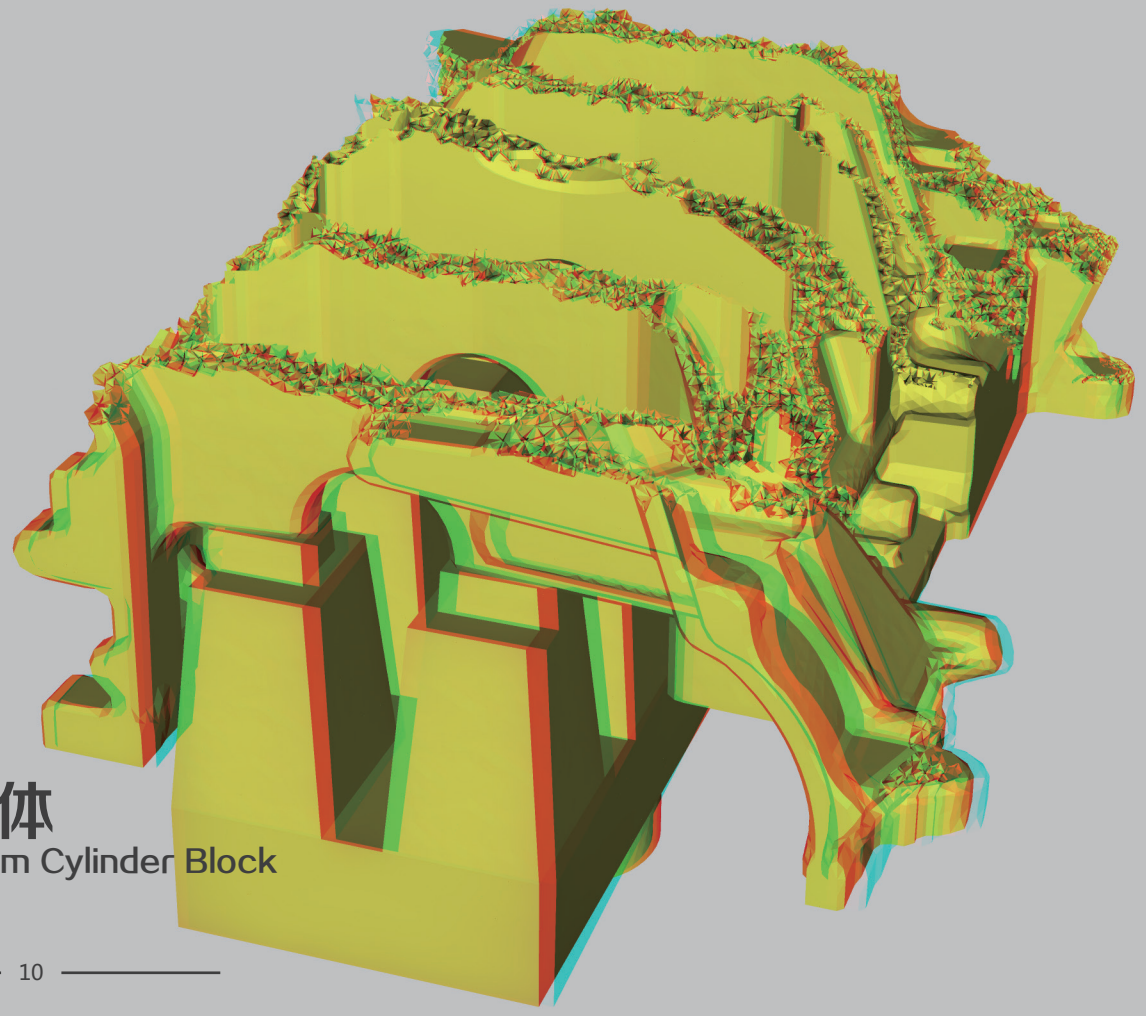
充型过程

Filling process

铝合金缸体
Case 01 Aluminum Cylinder Block

充型过程
Filling process





铝合金缸体

Case 01 Aluminum Cylinder Block

充型过程

Filling process