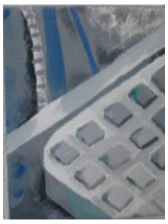

Chapter 4 Materials andProcesses

第四章 材料與工藝

Now that we have the structural foundation for the design, we’ll actually start this chapter with a “return to basics.” We’ve already touched upon the need to define and then conform to the product specification, but now we’ll return to cost considerations of the design. With that reestablishment of this design “touchstone,” we’ll continue on with more “building blocks” that will be available to the designer to determine the best materials and processes for their enclosure parts. The choice of material and process for the individual parts that make up the assembly will get the designer also thinking about the assembly and servicing of the product (which is taken up Chap. 6).

現在我們已經有了設計的結構基礎，我們將開始實際本章的“回歸基礎”。 我們已經談到了定義和然後遵循產品規格，但現在我們將回到設計的成本考慮。通過重新設計“試金石”，我們將繼續設計更多“構建塊”，設計師可以使用確定其外殼零件的最佳材料和工藝。 選擇組成裝配體的各個零件的材料和過程將獲得設計師還考慮了產品的組裝和維修（即佔用了第一章。 6）。

4.1 Cost Versus Time Versus Specification

4.1 成本與時間對規格

This chapter will start with a return to the basic consideration of the design, and that is an emphasis on cost being the deciding factor (ultimately) in the decision to make one choice over another in the design process.A designer of electronic enclosures faces a certain “practicality” in their design in that the design must be produced on a scale that assures financial success for the owners of the company. There would be certain designs that would be considered “one-offs,” where cost considerations are less important, but I’d like to address those designs that will produce assemblies (parts) that are at the very minimum, in the hundreds. I have worked at an experimental laboratory where only one assembly was to be produced, but again, I will not be addressing that case. Cost can even be extremely important in the case of a “one-off,” such as a space satellite, but the cost of failure could then dominate the design rationale. This is also true in matters of safety or public health. Let’s further explore the above cost emphasis on design. There are cases where prototypes required for the final design need to be developed. These “prototypes” are certainly less cost-sensitive, as it is time that is usually the critical factor here. However, even though the prototype itself may not have a cost-sensitivity, the overall project cost is impacted in the sense that cost is sacrificed for speed just in the prototype portion of the project, as that time saved (by the “high-cost” prototype) results in the product being tested and approved for production in a shorter length of time, which usually translates into an overall lower cost (for the project).

Let me give an example where a certain aspect of the design is originally thought to be the most important, but it is really cost that turns out to be the #1 consideration. If a corporation chooses “aesthetics,” that is, how a product looks and feels to the customer, as the #1 consideration, here is how that “plays out” in the marketplace. What is being decided by choosing “aesthetics” is actually a choice saying that these products will sell more with that look. So, the product development team’s investment in “aesthetics” will actually result in increased profit to the corporation (over a product with “lesser” emphasis on aesthetics).

So, when I say cost in the above paragraphs, that can be also thought of as profitability or (increased margin), that is, lower cost = higher profits.

Time plays into this “cost picture” very much. The “time-to-market” can be a huge driver in product development. That is, if a certain product isn’t released in some specific time frame (such as the spring planting season or the electronic show before the holidays), that can mean a huge difference to the total sales of the product. So, coupled with cost is the aspect of time. This leads to certain scenarios that are likely to play out in the life cycle of the product as:

本章將從返回設計的基本考慮開始，
強調成本是最終做出決定的決定性因素
在設計過程中一個選擇勝過另一個選擇。
電子外殼的設計師在設計中面臨一定的“實用性”
因為設計必須按一定規模生產，以確保
公司的所有者。某些設計將被考慮
“一次性”，其中成本方面的考慮不那麼重要，但我想談一談
那些將產生最少裝配體（零件）的設計，
數百。我在一個實驗實驗室工作，那裡只有一個組裝
是要製作的，但同樣，我將不討論這種情況。成本甚至可以
在“一次性”的情況下（例如太空衛星）極其重要，但是成本
失敗的原因將主導設計原理。在以下方面也是如此
安全或公共衛生。
讓我們進一步探討上述對設計的重視。在某些情況下

需要開發最終設計所需的原型。這些“原型”當然對成本不太敏感，因為時間通常是這裡的關鍵因素。然而，
即使原型本身可能不具有成本敏感性，但整個項目的成本
在某種意義上受到影響，因為僅在原型的一部分中就犧牲了速度成本
該項目，因為節省了時間（通過“高成本”原型）導致了產品
在較短的時間內被測試並批准用於生產
轉化為總體較低的成本（針對該項目）。
讓我舉一個例子，其中最初考慮了設計的某些方面
是最重要的，但實際上成本才是第一要考慮的因素。
如果公司選擇“美學”，即產品對產品的外觀和感覺如何
客戶是第一要考慮的因素，這就是在市場上“發揮”的作用。
選擇“美學”所決定的決定實際上是在說
這些產品將以這種外觀銷售更多。因此，產品開發團隊的
對“美學”的投資實際上將為公司增加利潤
（超過對美學的“較少”重視的產品）。
因此，當我在以上段落中說成本時，也可以認為是獲利能力或（增加的利潤），即較低的成本=較高的利潤。
時間在這個“成本圖”中扮演了非常重要的角色。 “上市時間”可以是
產品開發的巨大推動力。也就是說，如果某個產品沒有發布
一些特定的時間範圍（例如春季播種季節或電子展覽
假期之前），這可能意味著該產品的總銷售額存在巨大差異。因此，成本是時間的一部分。這導致某些情況
可能會在產品的生命週期中發揮作用，例如：

1. Emphasis on time in material/process/manufacturability choice for the early stages of the development process
2. A “high-production” and cost-reduced product release can come occur in the later stages of the development process All of this really still goes back to cost because it could have been determined (by the project management) that the overall cost is minimized by a “two-stage” product release (above). The overall sales, from the beginning of product release, to the end of product life, will be increased by this methodology. The concept of tooling needed for the project, and at what stage it is required, was explored in the section on Engineering Economy in Chap. 1. Cost can also be broken down into several time frames, such as:

1.儘早選擇材料/工藝/可製造性
開發過程的各個階段
2.在產品中可能會出現“高產量”和降低成本的產品發布。

開發過程的後期
所有這一切實際上仍要歸還成本，因為它可以確定
項目管理）通過“兩階段”產品將總成本降至最低
釋放（以上）。 從產品發佈到結束的整體銷售
這種方法將延長產品壽命。 工具的概念
本節探討了項目所需的內容以及所需的階段。
第一章工程經濟 1。
成本也可以細分為多個時間範圍，例如：

1. Development cost (until first shipment to customer)
2. Ongoing production cost of the product: materials/assembly/overhead
3. Service and warranty costs after production
4. End-of-life costs such as recycling

1.開發成本（直到首次交付給客戶）
2.產品的持續生產成本：材料/組裝/間接費用
3.生產後的服務和保修成本
4.報廢費用，例如回收利用

All of the costs added together make up the total cost – so minimizing cost in only one product phase doesn’t minimize the total cost. “Cost” is not only related to the cost of the individual part or assembly but also refers to the development (design) cost. Another example where cost is still the #1 driver of the project is a project where weight needs to be minimized for the product to succeed. This is rationalized by the following logic (for this made-up scenario):

所有加在一起的費用構成了總費用 – 因此，將
只有一個產品階段無法使總成本最小化。
“成本”不僅與單個零件或組件的成本有關，而且與
指開發（設計）成本。
成本仍然是項目第一推動力的另一個例子是
為了使產品成功，需要最小化重量。 這是合理的
以下邏輯（針對此組合方案）：

1. The specification of the product clearly calls out the:
・ Time required for the project delivery (expected)
・ Cost of product
・ Weight target of product (difficult to achieve)

2. Product is designed. Iteration #1 results in weight target exceeded.
3. Design is iterated; iteration #2 results in (slightly) exceeded weight target.
4. Time allotted to deliver product has been exceeded at this point.
5. Decision is made (by project management) to either:

1.產品規格明確指出：
・項目交付所需的時間（預期）
・產品成本
・產品重量目標（難以實現）
2.產品設計。 迭代 1 導致超出重量目標。
3.設計是迭代的； 迭代＃2 導致（略微）超出了體重目標。
4.此時已超過分配產品的時間。
5.（由項目管理人員）做出以下決定：

A. Accept iteration #2 (deviate from original specification)
B. Move on to iteration #3, with a specified length of time needed for completion and notation that original delivery time has been exceeded The above problem has its "roots" in weight minimization, but the solution is actually a matter of time (with time equating to cost). It's the cost of the project budget "overrun" that needs to be balanced with the need of product shipment. So, again, as time is related to cost, the product designer must have these two related project aspects (time and cost) at the forefront of their design "mind space." Those two, plus "conformance" (meet or exceeds) to specification, make for an integrated approach to successful design. Designers, if given any problem/challenge, must always be asking:

A.接受迭代 2（不同於原始規範）
B.繼續進行迭代 3，並指定完成完成所需的時間
並註明已超過原始交貨時間
上述問題的根源在於減輕重量，但解決方案是
實際上是一個時間問題（時間等於成本）。 這是項目的成本
預算"超支"需要與產品運輸的需求相平衡。
因此，同樣，由於時間與成本有關，產品設計師必須擁有這兩個
相關項目方面（時間和成本）位於其設計"思維空間"的最前沿。
這兩點加上規範的"符合性"（達到或超過），構成了
成功設計的綜合方法。
如果遇到任何問題/挑戰，設計師必須始終提出以下要求：

1. What is the acceptance criterion for the design? (How do I know I’ ve been a success?) This usually is in the form of a specification, which may be formal or informal. The design should be working to formalize the acceptance criterion so that this is completely transparent to the project team.
2. What is the budget for the design in terms of dollars?
3. What is the project schedule for individual parts, as it relates to the entire product, and what is the “critical path” of the schedule? If the time estimated to complete the task is too short (not enough time left), other solutions such as getting more resources must be suggested as soon as known. The detail of the schedule should be such that every time-intensive activity is noted, including design reviews needed to move forward and potential issue resolving time (second iterations of design) needed. all of the above is so important to the choice of:
・ Materials of the individual parts.
・ Process needed to produce the above parts.
・ Assembly procedure needed to assemble above parts.
・ Testing procedure needed to test above parts and assemblies.
・ Quality control procedures in place to assure parts and assemblies are produced and assembled to specifications.
・ Service (expected or unexpected) requirements are met.

1.設計的驗收標準是什麼？ （我怎麼知道我已經成功了？）這通常是規範的形式，可能是正式的或
非正式的。設計應致力於規範接受標準，因此
這對於項目團隊是完全透明的。
2.以美元計算的設計預算是多少？
3.與整個產品相關的各個部分的項目進度表是什麼，進度表的“關鍵路徑”是什麼？如果估計完成任務的時間太短（剩餘時間不足），則採用其他解決方案，例如
必須盡快建議更多資源。時間表的詳細
應該注意每個時間密集的活動，包括設計
進行審核所需的時間以及潛在的問題解決時間（第二次設計迭代）。
以上所有內容對於選擇以下內容非常重要：
・各個零件的材料。
・生產上述零件所需的過程。
・組裝上述零件所需的組裝程序。
・測試上述零件和組件所需的測試程序。
・制定質量控製程序以確保零件和組件的生產
並按照規格組裝。

・滿足服務（預期或意外）要求。

that this will bear repeating over and over in Chaps. 4 and 5, so I' ll just put the code "Cost (Chpt4)" in the text (the reader can just refer back to this general discussion as a refresher if needed).

這將在 Chaps 中反復出現。 4 和 5，所以我只輸入代碼
文本中的“費用（Chpt4）”（讀者可以參考此一般性討論
如有需要，請作為複習）。

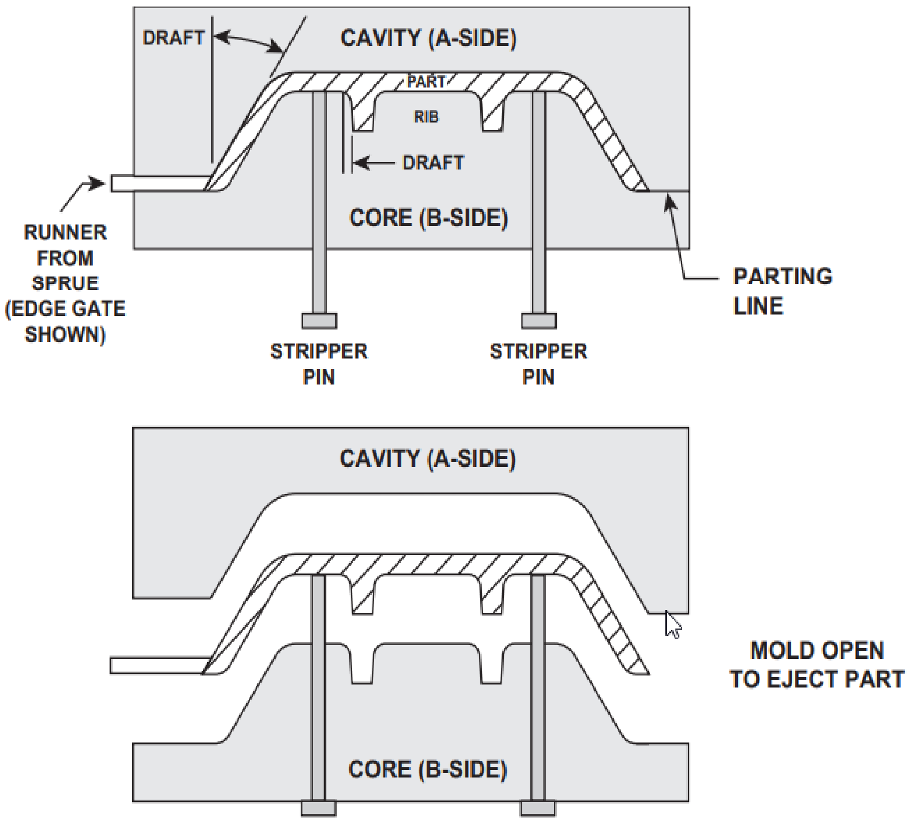

Fig. 4.1 Injection molding – mold schematic

圖 4.1 注射成型 – 模具示意圖

4.2 The Designer' s Mind Space

4.2 設計師的思維空間

The designer has to “think ahead.” When faced with designing an electronic enclosure, here are some things that go on in the mind of a designer, hopefully, all at the same time (Cost (Chpt4)). I consider these the following questions to be “everpresent” in the designer’s head, which is why I use the term “designer’s mind space” to describe these ever-present questions:

設計師必須“先思考”。 在設計電子機櫃時，希望設計師在腦海中想到一些事情。
同一時間（費用（Chpt4））。 我認為以下這些問題在設計師的腦海中是“永遠存在的”，這就是為什麼我使用術語“設計師的思想空間”
描述這些永遠存在的問題：

・How big?
・ How many parts are needed to accomplish purpose?
・ Has this (or a slight variation) been done before? Here, or at another company? How has the product purpose been accomplished by the competition?
・ What is the “user interface,” that is, how will the customer use this product (buttons/displays/lights/doors/connections for power, input, and output)?
・ I am designing this portion of the product, what are the other portions that I am not (directly) responsible for?
・ How quickly can I present some ideas that will solve the problem? How quickly can I prototype these ideas to check out the feasibility of an idea? Who else can I brainstorm with to critique these ideas?
・ Once the idea has been reviewed and the prototype seems to work, what parts of the design are:
・ The most risky (may not work as intended)?
・ The most simple?
・ The longest lead items for a preproduction run of parts, that is, what are the parts that are in the “critical path” of project completion?

・多大？
・完成目標需要多少部分？
・是否曾經做過（或稍作改動）？在這裡，還是在另一家公司？
競爭如何實現產品目的？
・什麼是“用戶界面”，即客戶將如何使用該產品（按鈕，顯示屏/燈/門/電源/輸入和輸出的連接）？
・我正在設計產品的這一部分，我還需要其他哪些部分
不（直接）負責？

・我多快提出一些解決問題的想法？太快了
我可以原型化這些想法以檢查一個想法的可行性嗎？還有誰可以
我會集思廣益來批評這些想法嗎？
・一旦想法被審核並且原型似乎可以正常工作，那麼
設計是：
・風險最大（可能無法按預期工作）？
・最簡單？
・零件的預生產運行中最長的鉛項目，即零件是什麼
在項目完成的“關鍵路徑”上？

For the prototype, how close is it to the production version? What testing will determine whether the prototype "succeeds" or "fails," and are several rounds of prototyping required (each round perhaps nearer to the production version)? How many prototypes does the project team need? And when? How will I convey project progress or issues with the design to the rest of the design team? Who needs to be there for a design review?

對於原型，它與生產版本有多接近？ 什麼測試會
確定原型是“成功”還是“失敗”，並且經過幾輪
需要原型製作（每輪可能更接近生產版本）？ 怎麼樣
項目團隊需要許多原型？ 什麼時候？
我將如何向其他人傳達項目進度或設計問題
設計團隊？ 誰需要在那裡進行設計審查？

4.3 Materials andProcess Choice

4.3 材料和工藝選擇

Once a designer has designed a part, the designer must determine the "best" Cost (Chpt4) way for that part to be produced. The general items to be determined for each part are:
設計人員設計完零件後，必須確定“最佳”成本
（Chpt4）生產該零件的方式。 要確定的一般項目
每個部分是：

- Material of the part.
- Finish required for the part (see next section).
- Dimensional accuracy needed for the part.

・ Process by which that part will be produced (perhaps one process for early needs, prototyping, and preproduction of parts and a different process for mature production of the parts).
・ Quantity needed of the part (say, per quarter, per month, per year).
・ Second operations needed for the part (beyond finishing).
・ Cost requirements for the part.
・ Can this part be combined with another part in the design? Essentially, what needs to be determined is whether a single (combined) part can fulfill the functionality of the separate parts (Cost (Chpt4)). ・ Can the part be made symmetrical (for assembly ease)? Should the part that is almost symmetrical be made a more obvious nonsymmetrical part? These two questions deal with the assembly of this part and the chances of being assembled in an incorrect way. Holes or notches (superfluous) can be added to the part solely for the purpose of making that part symmetrical.

・零件的材料。
・零件需要的表面處理（請參閱下一節）。
・零件所需的尺寸精度。
・生產零件的過程（也許是早期需求的一個過程，
零件的原型製作，預生產以及零件成熟生產的不同過程）。
・零件所需的數量（例如，每季度，每月，每年）。
・零件需要的第二次操作（超出精加工）。
・零件的成本要求。
・該部分可以與設計中的另一部分組合嗎？本質上，什麼
需要確定的是單個（組合）部件是否可以滿足單獨部件的功能（成本
（Chpt4））。
・零件可以做成對稱的（為了便於組裝）嗎？應該的部分是
幾乎對稱會成為更明顯的非對稱部分？這兩個
問題涉及這部分的組裝以及組裝的機會
以不正確的方式。可以在零件上添加孔或缺口（多餘的）
僅出於使該零件對稱的目的。

Considerations for determining material selection for a part: The designer should choose a material that will satisfy (meet or exceed):
1. Strength requirements
2. Weight requirements
3. Reliability requirements
4. Regulatory requirements
5. Safety requirements 4.3 Materials andProcess Choice

6. Thermal requirements
7. Shielding requirements (EMI/RFI)
8. Compatibility requirements for metals (galvanic corrosion)
9. Elastic requirements (durometer)
10. Conductive (or insulating) requirements
11. Opaqueness requirements
12. Wear requirements
13. Aesthetical requirements (touch, visual)
14. Acoustical requirements
15. Ultraviolet (UV) transmission and resistance requirements Let’ s go thru a few examples and see how the 15 requirements above get determined (Cost (Chpt4)).

確定零件的材料選擇的注意事項：
設計者應選擇滿足（超過）要求的材料：
1.強度要求
2.重量要求
3.可靠性要求
4.法規要求
5.安全要求
4.3 材料和工藝選擇
6.散熱要求
7.屏蔽要求（EMI / RFI）
8.金屬的兼容性要求（電腐蝕）
9.彈性要求（硬度計）
10.導電（或絕緣）要求
11.不透明要求
12.磨損要求
13.審美要求（觸覺，視覺）
14.聲學要求
15.紫外線（UV）傳輸和電阻要求
我們來看幾個示例，看看如何確定上述 15 個要求（成本（Chpt4））。

Example 1 Cell Phone (Outer) Case For the choice of material, two major candidates come to mind; this would be either a metal or a plastic. Either can fulfill the 15 requirements, with these notations:

示例 1：手機外殼
在選擇材料時，我想到了兩個主要的候選人。 這可能是
金屬或塑料。 可以使用以下符號滿足 15 個要求：

1. Metal will provide adequate EMI shielding but may be difficult to fabricate. The case needs to be smooth and elegant, which is expensive for a metal to accomplish – even a casting can require many “second operations” (such as machining or grinding) that can be labor-intensive.
2. Plastic (injection molded) will be adequate for alleviating the “smoothness” and “elegance” criteria but will need an additional EMI shielding scheme. Either the plastic case must be “metalized” or another nonaesthetic part needs to be added to the design just under the plastic case to function as an EMI shield. We also will need to investigate some safety issues with plastics (UL regulations for “flame class”). A plastic case as an exterior part could have much lower costs required for finishing (no painting required, at least that is the hope).
3. If weight (and size) is a factor (usually is with a cell phone), both metal and plastic should be examined more closely to see what may be better. Normally, ribs can be added to a plastic design to augment strength.
4. Thermal issues can be a factor in choice of material. A plastic will function as an insulator (keeping in the heat), while a metal will take the internal heat generation away to the ambient air resulting in a lower “case ambient” temperature. However, the metal case may feel too hot to the touch.

1.金屬將提供足夠的 EMI 屏蔽，但可能難以製造。的
外殼需要光滑，優雅，這對於金屬的製造來說是昂貴的 – 即使鑄造也可能需要
許多“第二次操作”（例如機加工）
或打磨)，可能會佔用大量人力。
2.塑料（注塑）足以緩解“光滑度”和
“優雅”標準，但需要額外的 EMI 屏蔽方案。要么
塑料外殼必須“金屬化”，或者需要添加其他非美學部件
塑料外殼下方的設計起到 EMI 屏蔽的作用。我們也會
需要調查塑料的一些安全問題（UL 關於“火焰的規定”
類”)。塑料外殼作為外部零件可能需要更低的成本
完成（不需要繪畫，至少是希望)。
3.如果重量（和尺寸）是一個因素（通常是手機)，則金屬和
應該更仔細地檢查塑料，看看有什麼更好的方法。一般，
可以將肋骨添加到塑料設計中以增強強度。
4.散熱問題可能是選擇材料的一個因素。塑料將充當
隔熱層（保持熱量)，而金屬會將內部產生的熱量帶走到周圍的空氣中，從而降低“外殼周圍”的溫度。
但是，金屬外殼摸起來可能會太熱。

Calculating equivalent rigidity (or stiffness) of a material is shown quite succinctly in Ref. [1], where (temperature-dependent qualities):
T1 = cube root of ((E2/E1) × T23
) = Thickness of Material 1
E1 = Flexural modulus of Material 1
E2 = Flexural modulus of Material 2
T2 = Thickness of Material 2
Let’ s compute the equivalent thickness of a plastic (say, SABIC Cycolac) to a 0.03 inch thick aluminum part:
Tplastic = cube root of ( ) ( ) 100 4 0 ×( ) 03 = 0 088 inch
Let’ s compute the equivalent thickness of titanium to a 0.03 inch thick aluminum part:
Titanium = cube root of ( ) ( ) 100 160 ×( ) 0 03 0 = 026 inch 3
/ . .
Now, if we look at strength (all of the above are “equivalent” strengths) to weight ratios for (looking at thickness to density ratio):
Plastic = 0 088 0 04 2 = 2 in lb
Aluminum = 0 030 0 10 0 = 3in lb
Titanium = 0 026 0 16 0 = 16 in lb

参考文獻中非常簡潔地顯示了計算材料的等效剛度（或剛度）。 [1]，其中（與溫度有關的品質）：
T1 =（((E2 / E1）×T23
）=材料 1 的厚度
E1 =材料 1 的彎曲模量
E2 =材料 2 的彎曲模量
T2 =材料 2 的厚度
讓我們計算塑料（例如 SABIC Cycolac）與
0.03 英寸厚的鋁製零件：
Tplastic =（）（）100 4 0×（）03 的 0 088 英寸的立方根
讓我們計算出與 0.03 英寸厚的鋁等效的鈦厚度
部分：
鈦=（）（）100160×（）的立方根 0 03 0 = 026 英寸 3

現在，如果我們看一下力量（以上所有都是“等效”力量）對重量的影響
的比率（從厚度到密度的比率來看）：
塑料= 0088 0 04 2 = 2 磅

鋁= 0 030 0 10 0 = 3 英寸磅
鈦= 0 026 0 16 0 = 16 英寸磅

Therefore, if weight (for equivalent strength) is an issue, titanium would be a much better choice (than aluminum or plastic). This is why titanium is extensively used in aircraft (Cost (Chpt4)); however, titanium has some inherent fabrication difficulties which make it very expensive as a choice for an electronic enclosure. Discussion on molding plastics is in a following subchapter.
No decision will be made here of using "metal vs. plastic" for the exterior case of the enclosure. Enough ambiguities have been raised as to warrant a much more in-depth analysis, and we need to move on to another example of material choice.
The Apple 5s phone case was made of (machined) aluminum, while the later released Apple 5c phone case was made of plastic. The plastic was made EMI compliant with the addition of a metalized coating in some areas and metal shields in other areas. The plastic version was thought to "bend" in the shirt pocket much more easily, but not enough to stub sales. Machined aluminum was a much "sooner to market" choice over molded plastic, as long lead time tooling was not required. Also, changes can be made much more adroitly with a machined piece than a molded part due to the longer time needed to modify the tool and test the new change. Again, each design will likely be unique to material and process choice – this is an example of something the mechanical engineer (working with other teams in the corporation) can make to the overall product design.
The optimum choice between plastics and die castings requires careful analysis of all product requirements.
Aluminum, magnesium, zinc, and zinc-aluminum (ZA) die castings are often preferred over plastics in electronic enclosures where strength, stiffness, and minimum packaging space are required. They often eliminate the need for inserts to received threaded fasteners. Their thermal conductivity often eliminates the need for cooling fans, which is essential in battery-operated portable electronic equipment. Die castings are also preferred over plastics where strength and rigidity are required and for medium to large size decorative components operating at elevated temperatures.
EMI and RFI (electromagnetic interference and radio-frequency interference) shieldings are inherent with die castings as they are metal. Plastic parts need a layer of metal shielding to provide EMI/RFI compliance. These shielding additions for plastic parts (painting, coating, resin fillers, metallic barriers, multilayered electroless nickel plating) can have performance problems and quality control issues.
Aluminum die castings are frequently chosen over plastics in designs that are subject to continuous pressure, particularly at elevated temperatures, and hand tools

such as drills that require minimum weight, rigidity, and good surface quality.
Magnesium die castings are frequently chosen in applications that require minimum weight combined with strength, stiffness, and minimum packaging space.
Components for high-speed printers, which require rigidity at minimum weight; cases requiring mounting features, high-quality surface, and impact resistance; and decorative trim pieces are frequently produced by magnesium die casting.
Plastic components that are subjected to continuous loads, such as a part being used to environmentally seal, often require support from metal stampings to develop stiffness and creep resistance.
Also, it should be noted that even a "simple" material such as aluminum is much more complicated to actually specify in an engineering drawing. Many grades and alloys of aluminums exist, either "commonly" or "exotically," and this text is not going to address that complication, only to say that much attention is deserved to actually specify the specific "grade" of the material. Picking one grade over another is a function of that particular grade's ability to (Cost (Chpt4)):

因此，如果重量（等效強度）成為問題，則鈦將成為
比鋁或塑料更好的選擇。這就是為什麼鈦廣泛存在的原因
用於飛機（成本（Chpt4））；然而，鈦具有一些固有的製造困難，這使其作為電子外殼的選擇非常昂貴。
關於塑料模製的討論在以下子章節中。
此處不會決定使用"金屬還是塑料"作為外殼
外殼的。人們提出了足夠多的歧義，以確保更多
深入分析，我們需要繼續進行材料選擇的另一個例子。
Apple 5s 手機殼由（機加工）鋁製成，而後者
發布的 Apple 5c 手機殼由塑料製成。通過在某些區域添加金屬化塗層並在其中添加金屬屏蔽層，使塑料符合 EMI 要求。
其他地區。塑料版本被認為在襯衫口袋中"彎曲"得多
輕鬆，但不足以阻止銷售。機加工鋁材"
"市場"而不是模製塑料，因為不需要很長的交貨時間工具。
而且，與機械零件相比，使用機械零件可以更輕鬆地進行更改。
成型零件，因為修改工具和測試新零件需要更長的時間
更改。同樣，每種設計對於材料和工藝選擇可能都是唯一的－
這是機械工程師（與其他團隊合作）的一個例子
在公司）可以對整體產品進行設計。
塑料和壓鑄件之間的最佳選擇需要仔細分析
所有產品要求。

鋁，鎂，鋅和鋅鋁（ZA）壓鑄件通常比強度，剛度和最小值最小的電子外殼中的塑料更受歡迎
需要包裝空間。他們通常消除了插入插件的需要
螺紋緊固件。它們的導熱性通常消除了冷卻的需要
風扇，這在電池供電的便攜式電子設備中必不可少。對於要求強度和剛度的塑料，壓鑄件也比塑料更可取。
在高溫下運行的中型到大型裝飾部件。
EMI 和 RFI（電磁干擾和射頻干擾）
壓鑄件是金屬，因此是壓鑄件固有的。塑料零件需要一層
金屬屏蔽層以符合 EMI / RFI 要求。這些用於塑料部件（油漆，塗料，樹脂填料，金屬阻擋層，多層化學鍍鎳）的屏蔽添加劑可能會有性能問題和質量控制問題。
在以下設計中，鋁壓鑄件通常比塑料更受歡迎
承受持續壓力（尤其是在高溫下）和手動工具
例如要求最小重量，剛度和良好表面質量的鑽頭。
鎂壓鑄件經常在要求最低限度的應用中選擇
重量加上強度，剛度和最小包裝空間。
用於高速打印機的組件，需要最小重量的堅固性；
需要安裝功能，高質量表面和耐衝擊性的外殼；和
裝飾性裝飾件通常通過鎂壓鑄生產。
承受連續載荷的塑料部件，例如零件
用於環境密封，通常需要金屬沖壓件的支持才能開發
剛度和抗蠕變性。
另外，應該注意的是，即使是“簡單”的材料，例如鋁
在工程圖中實際指定更為複雜。許多年級和
鋁的合金以“普通”或“異乎尋常”的形式存在，而本文並非
將要解決的並發症，只是說值得關注
實際指定材料的特定“等級”。選一個成績勝過另一個
是該特定年級的（Cost（Chpt4））能力的函數：

1. Possess the 14 characteristics (stated above) of the design.
2. Be available to any of the supply chain members for meeting delivery times.
3. Be fabricated in a repeatable manner with specified quality control measures.
For example, if I wanted a part to be made of stainless steel, items to be considered would be:

1.具備設計的 14 個特徵（如上所述）。
2.可供任何供應鏈成員使用以達到交貨時間。

3.採用指定的質量控制措施，以可重複的方式製造。
例如，如果我希望零件由不銹鋼製成，則要考慮的項目是：

1. Choice between chromium nickel stainless steels (austenitic) and straight chromium stainless steels (martensitic). Chromium nickel stainless steels are Types 20X and Types 3XX. For example, Type 302 is (from Ref. [2]):

・ The basic 18% Cr. 8% Ni, analysis, possessing excellent corrosion resistance to many organic and inorganic acids, and their salts at ordinary temperature.

・ Has good resistance to oxidation at elevated temperatures.

・ Can be readily fabricated by all methods usually employed with carbon steels.

・ Cr-Ni grades are nonmagnetic in the fully annealed condition and cannot be hardened by conventional heat treatment.

In Ref. [2], Tables of Information (for the various grades of stainless steel): chemical composition, physical data, and the mechanical properties (both in the annealed and heat-treated states) are shown.

2. Availability must be considered for the candidates (choices) of material. In this example for stainless steel, by checking a reference such as Ref. [3], Type 302 is not readily available. Types 304, 309, 316, and others are available in stock (from Ryerson, a large resource of stainless steel stock). For example, Type 316 (cold rolled, annealed, pickled, 2B and 3 finish. Spec: QQ-S-766), ASTM-A240, is available in 16 gauge (0.060 thick) × 30 inch × 96 inch size stainless steel sheet.

3. Material choice should be made with fabrication technique in mind. If the part is envisioned to be turned on a spindle machine (lathe or mill), then a freemachining grade needs to be considered. If the part is to be welded, various grades may or may not be very weldable.

4. As usual, information about the material choice can be utilized using experience from:

・ Your codesigners within your own group (or other corporate resources),

・ Your supply chain fabricators

1.在鉻鎳不銹鋼（奧氏體）和直鉻不銹鋼（馬氏體）之間選擇。鉻鎳不銹鋼類型
20X 和 3XX 類型。例如，類型 302 是（來自參考文獻[2]）：

・基本的 18%Cr。鎳含量為 8%，具有出色的耐腐蝕性
在常溫下會分解為許多有機和無機酸及其鹽。

・在高溫下具有良好的抗氧化性。

・可以通過通常用於碳鋼的所有方法輕鬆製造。

・Cr-Ni 等級在完全退火狀態下是非磁性的，不能

通過常規熱處理硬化。
在參考文獻中[2]，信息表（適用於各種等級的不銹鋼）：
化學成分，物理數據和機械性能（均在
（退火和熱處理狀態）。
2.必須考慮材料的候選人（選擇）的可用性。在這
通過檢查諸如 Ref。 [3]，類型 302 是
不容易獲得。庫存有 304、309、316 等類型（從
瑞爾森，大量的不銹鋼庫存資源。例如，類型 316（冷
軋製，退火，酸洗，2B 和 3 精加工。規格：QQ-S-766），ASTM-A240，
提供 16 規格（0.060 厚）×30 英寸×96 英寸尺寸的不銹鋼板。
3.在選擇材料時應考慮製造技術。如果零件是
考慮到要在主軸機床（車床或銑床上）上旋轉，則需要考慮自由加工等級。如果要焊接零件，各種
牌號可能很難焊接。
4.像往常一樣，可以根據經驗利用有關材料選擇的信息
從：
• 您自己的組（或其他公司資源）中的代碼簽名者，
• 您的供應鏈製造商

Once the material choice is made, it must be fully specified, that is, specified so that it will be unambiguous on the part specification. Materials and finishes are usually specified to some standard such as ASTM, MIL-standard (US government), or international standards such as ISO/IEC.There must also be in place some methodology of assuring (thru standard quality control procedures) that the material specified is the material being fabricated into the final part.

做出材料選擇後，必須完全指定，即指定
這在零件規格上將是明確的。 材料和表面處理通常指定為某些標準，例如
ASTM，MIL 標準（美國政府）或
國際標準，例如 ISO / IEC。 還必須採用某種方法（通過標準質量控製程序）來確保所指定的材料是要製成最終零件的材料。

Example 2 Cover for a LED Let’s take another example of a material choice and the “thought process” that one would go thru to make a rational choice among candidate materials. How about the need for a clear (optically transparent) part that will cover an LED? This part is envisioned to be flat and not needing much structural strength, basically supporting its own weight and preventing the user from “poking” the LED with their finger or a pencil. Let’s name the part “LED window” for now. The piece will “seal off” the LED (from moisture) and is not generally replaceable (must last the product lifetime without being serviced). Immediate questions that should come to the designer’s mind are (Cost (Chpt4)):

示例 2：LED 燈罩
讓我們再舉一個物質選擇和“思想過程”的例子
將在候選材料中做出合理選擇。
那麼需要一個透明（光學透明）的零件來覆蓋一個
發光二極管？ 可以設想這部分是扁平的，不需要太多的結構強度，
基本上可以支撐自己的體重，並防止用戶“戳” LED
用他們的手指或鉛筆。 現在將其命名為“ LED 窗口”。 那一塊
將“密封” LED（防潮），並且通常不可更換（必須持續使用
產品使用壽命而無需維修）。
設計師應該立即想到的問題是（成本（Chpt4））：

1. How many are to be produced, what is the schedule for part production (prototype/preproduction/production), and at what general cost? The cost is usually not specified up front in the design, that is, it may be something ambiguous such as “as cheap as possible.” As the design proceeds, certain choices in the design may increase the cost of the part, so trade-offs with alternatives are usually helpful.
2. Will it be designed to fit into a recess or “stand out” from the enclosure? How far away will the window be from the LED? These are the general “geometry” issues of the design. What are the aestetic considerations of the window?
3. The light from the LED shines thru this part. Is there a need for the light (from the LED) to be “diffused” – what kind of look do we want aesthetically? How does this part look in the “overall” design? Is it in the user’s view all the time or only occasionally? Is “clear” the right choice of color, or is there another color that is wanted (red/green/amber/blue)? What color is the light from the LED?
4. Go thru the 15 requirements for the material from the above characteristics. For example, how is the part (right now, a nonmetal) going to adversely affect the EMI shielding requirements? This could possibly lead to the new part being as small as possible to create a minimum hole for EMI.
5. How will the LED window be assembled to the enclosure? Can it be assembled without any extra hardware? Candidates for assembly may be the use of ultrasonics, tape, or adhesive to bond the piece into place.
6. Are there multiple (more than one) “windows” in the overall design? Look for commonality possibilities with these windows.
7. Material candidates (with some issues for that choice):

・ Lexan plastic: Molded or cut from sheet? If molded, can we see mold flow lines? If cut from sheet, it probably will be flat (no other geometric features), while molding allows a design feature to be added (such as an ultrasonic weld bead). How thick? Is there an “anti-scratch” or “antiglare” requirement (and how would that be solved?)? If molded, can the window be assembled to the enclosure at the enclosure fabricator? Plastic will have some safety considerations such as being a burn hazard or having sharp edges.

・ Glass: Hardest and toughest material candidate, probably the most expensive (Cost (Chpt4)).

・ Polyester film as part of a label: Usually under 0.010 inch thick. Label could incorporate other information on the enclosure including identifying what the LED functions are.

8. Present to the project team with whatever detail is warranted. This could be price/time estimates, prototypes, or sketches to base going forward with a design choice for material.

1.將要生產多少，零件生產的時間表（原型/預生產/生產）是什麼，以及一般的成本是多少？費用通常不
在設計中預先指定，也就是說，可能有些含糊，例如
“盡可能便宜。”隨著設計的進行，設計中的某些選擇可能會
增加零件的成本，因此通常需要進行折衷選擇。
2.它的設計是否適合裝入凹槽或從外殼“突出”？多遠
窗戶將離開 LED 嗎？這些是一般的“幾何”
設計問題。窗口的美學考慮因素是什麼？
3. LED 發出的光穿過該部分。是否需要照明（來自
LED）被“擴散” – 我們在美學上想要什麼樣的外觀？怎麼樣
這部分是否在“整體”設計中尋找？是否一直在用戶視圖中顯示？
只是偶爾？是“清除”正確的顏色選擇，還是有其他顏色
想要的（紅色/綠色/琥珀色/藍色）？ LED 發出的光是什麼顏色？
4.從以上特性出發，通過對材料的 15 項要求。對於
例如，零件（現在是非金屬）將如何對零件產生不利影響
EMI 屏蔽要求？這可能導致新的部分成為
盡可能地小以產生最小的 EMI 孔。
5. LED 窗如何組裝到外殼上？可以組裝嗎
沒有任何額外的硬件？組裝的候選人可能是使用超聲波，膠帶或粘合劑將零件粘合到位。
6.總體設計中是否有多個（不止一個）“窗口”？尋找
這些窗口的通用性。

7.重大候選人（有一些問題可供選擇）:
・Lexan 塑料：是模壓還是切割而成？如果是模製的，我們能看到模子流動嗎
線？如果是從薄片上切下的，則可能是平坦的（沒有其他幾何特徵），
同時成型允許添加設計特徵（例如超聲波焊接）
珠子）。多厚是否有“防刮擦”或“防眩光”要求（並且
如何解決？）？如果是模製的，可以將窗戶組裝到
機櫃製造商處的機櫃？塑料將具有一些安全考慮，例如有燒傷危險或邊緣鋒利。
・玻璃：最堅硬和最堅硬的材料候選者，可能是最昂貴的
（費用（Chpt4））。
・作為標籤一部分的聚酯薄膜：通常小於 0.010 英寸厚。標籤可以
將其他信息併入機箱，包括確定哪些
LED 功能。
8.保證將任何細節呈現給項目團隊。這可能是
設計所需的價格/時間估算，原型或草圖
材料的選擇。

4.4 Finishes andCoatings

4.4 飾面和塗層

All of the choices made when selecting a material (previous selection) are directly “coupled” with the choice of finish for that material. Practically all engineered parts need a finish. There would be some exceptions to this, for example, a “sculpture” (artwork) or building façade that is intended to corrode (and have a “corroded” look). The designer will be specifying both a material and a finish to every part they design. Finishes (including coatings in the broad sense) are required to:

選擇材料（先前選擇）時所做的所有選擇都直接
與該材料的表面處理選擇“耦合”。 幾乎所有工程零件
需要完成。 對此會有一些例外，例如“雕塑”
（藝術品）或旨在腐蝕（並具有“腐蝕”
看）。 設計師將為每個零件指定材料和飾面
設計。
面漆（包括廣義的塗料）必須：

1. Retard corrosion in storage (from fabricator, to assembler, to customer) or in final usage by the customer.
2. Provide anodic protection when metals are in contact with dissimilar metals. Basic to this, dissimilar metals in contact must have adequate protection against galvanic corrosion. This is accomplished by interposing inert material or that which is compatible to each. The table below lists similar metals by groups. Contact between a material of one group and another material of the same group shall be considered as similar. Conversely, a critical electrolytic stage is set (requiring only humidity as the agent) whenever materials of different groups are in intimate contact. (This is particularly disadvantageous when either magnesium or aluminum, unprotected, is in contact with any other metals of different groups (Table4.1).)

1.延緩腐蝕（從製造商，組裝商到客戶）或在倉庫中腐蝕
客戶的最終使用權。
2.當金屬與異種金屬接觸時，提供陽極保護。
在此基礎上，接觸的異種金屬必須具有足夠的保護以防
電腐蝕。 這是通過插入惰性材料或
每個都兼容。 下表按組列出了相似的金屬。
一組材料與同一組另一種材料之間的接觸
應視為相似。 相反，設置了關鍵的電解階段
（僅要求濕度作為媒介）不同類別的材料
親密接觸。 （當未保護的鎂或鋁與任何其他不同金屬接觸時，這尤其不利
組（表 4.1）。）

Table 4.1 Material groups

Group I	Group II	Group III	Group IV
Magnesium alloys	Aluminum	Zinc	Copper
	Aluminum alloys	Cadmium	Copper alloys
	Zinc	Steel	Nickel
	Cadmium	Lead	Nickel alloys
	Tin	Tin	Chromium
	Stainless steel	Stainless steel	Stainless steel
			Gold
			Silver

Note that the uses of lead, cadmium, and, in fact, all finishing materials have very serious environmental concerns. Many of these materials are banned or limited by various legislative statutes and laws. Please see the RoHS requirements as an example of these international laws that limit the use of one or more of the above finishes.

表 4.1 物料組
請注意，使用鉛，鎘以及實際上所有的精加工材料
非常嚴重的環境問題。 其中許多材料被禁止或
受各種立法法規和法律的限制。 請參閱 RoHS 要求
作為這些國際法的一個例子，限制了一項或多項
以上完成。

3. Appearance (aesthetics).
4. In the case of bonded connections, the protective coating will actually be omitted (masked). For such areas, moisture entrance must be prevented by forced ventilation or adequate sealing. Finishes are usually listed into three main types: (See Ref. [4, 5]) • Chemical: those finishes resulting from chemical reactions on the surface of the metal. • Electroplated: those finishes consisting of a film or plate deposited on the base metal of electrolytic action. • Organic: finishes consisting of an organic coating over a base material, applied usually by brushing, dipping, or spraying

3.外觀（美學）。
4.對於鍵合連接，實際上將省略保護塗層
（已屏蔽）。 對於此類區域，必須通過強制通風或適當密封來防止水分進入。
整理劑通常分為三種主要類型：(參見參考文獻[4，5])
・化學製品：由於表面化學反應產生的那些飾面
金屬。
・電鍍：由底材上沉積的膜或板組成的那些飾面
電解金屬。
・有機：由在基材上的有機塗層組成的面漆，已塗
通常通過刷，浸或噴

Coatings can be applied by:
• Sprayed metal: A thin layer of metal is sprayed onto the surface for several purposes. Examples are aluminum being used for corrosion and heat resistance or copper for electrical conductivity.
• Powder coating: A dry painting process in which powder particles are applied directly to the surface to be coated without the use of solvents or water. Either thermosetting or thermoplastic powders are used. Parts are electrostatically powder sprayed at room temperature and then heated above the melting point of the powder to attain a fused surface finish.
• Electrodepositing: A thin coating can be deposited electrically to improve

appearance, increase electrical qualities, and increase resistance to wear, corrosion, or specific environments.

・ Ceramic, cermet, and refractory: Fixed porcelain enamel frits and refractory materials are used as corrosion-resistant coatings and also for color appeal and decorative effect.

・ Hot dipping: These coatings, used principally on steel, cast iron, and copper, provide corrosion resistance at low cost. Materials used are aluminum, zinc, lead, tin, and lead-tin.

・ Immersion: These coatings can be applied to most ferrous and nonferrous metals, with a few exceptions. Materials used are nickel, tin, copper, gold, silver, and platinum. Examples of use are for conductivity, facilitation of soldering, and brazing.

・ Diffusion: These coatings are produced by the application of heat while the base material is in contact with a powder or solution. Most diffusion coatings are intended to obtain hard and wear-resistant surfaces and to increase resistance to corrosion.

・ Vapor deposited: This is depositing vaporized metal in a vacuum chamber, where it then condenses on all cool surfaces. Most metals and nonmetals can be used as base materials to be coated. Examples are mirrors and optical reflectors, metalized plastics, lens coatings, and instrument parts.

・ Organic: These consist of alkyds, celluloses, epoxies, phenolics, silicones, vinyls, rubbers, and others.

・ Chemical conversion: These are chemical coatings which react with the base metal to produce a surface structure that will improve paint bonding, corrosion resistance, decorative properties, and wear resistance. Phosphate, chromate, anodic, and oxide coatings are common.

・ Rust prevention: These are oils, petroleum derivatives, and waxes that form a film which will resist attack, principally from industrial and marine atmospheres.

可以通過以下方式施加塗層：

・噴塗金屬：出於多種目的，在表面上噴塗了一層薄金屬。例如，鋁被用於耐腐蝕和耐熱性，或者
銅用於導電。

・粉末塗料：乾式噴塗工藝，其中應用粉末顆粒
直接在不使用溶劑或水的情況下塗覆到要塗覆的表面。要么
使用熱固性或熱塑性粉末。零件在室溫下用靜電粉末噴塗，然後加熱到熔點以上。
粉末以獲得融合的表面光潔度。

・電沉積：可以電沉積薄塗層以改善
外觀，提高電氣質量並提高對磨損，腐蝕或特定環境的抵抗力。

・陶瓷，金屬陶瓷和耐火材料：固定的搪瓷玻璃料和耐火材料
該材料用作耐腐蝕塗料，還可以用於增添色彩和
裝飾效果。
・熱浸：這些塗料主要用於鋼，鑄鐵和銅上，
提供低成本的耐腐蝕性。使用的材料是鋁，鋅，
鉛，錫和鉛錫。
・浸入：這些塗料可用於大多數黑色和有色金屬，
除少數例外。使用的材料是鎳，錫，銅，金，銀和鉑。用途示例包括導電性，
便於焊接和釬焊。
・擴散：這些塗料是通過在基體上加熱而產生的
材料與粉末或溶液接觸。大多數擴散塗料均用於
以獲得堅硬且耐磨的表面並提高抗腐蝕性。
・蒸汽沉積：這是在真空室中沉積汽化金屬，
然後它凝結在所有涼爽的表面上。大多數金屬和非金屬可用作
要塗覆的基礎材料。示例包括鏡子和光學反射鏡，金屬化塑料，鏡片塗層和儀
器部件。
・有機物：由醇酸樹脂，纖維素，環氧樹脂，酚醛樹脂，有機矽，
乙烯基，橡膠等。
・化學轉化：這些是與鹼反應的化學塗層
金屬產生的表面結構將改善塗料的粘結，腐蝕
耐性，裝飾性和耐磨性。磷酸鹽，鉻酸鹽，
陽極和氧化物塗層是常見的。
・防銹：這些是形成膜的油，石油衍生物和蠟
它將抵抗主要來自工業和海洋大氣層的攻擊。

Finishes or coatings that will be applied to engineering materials are usually called out on the (part) documentation with a MIL specification (MIL SPEC) Cross Reference. This is mainly done because most (common) finishes already are standardized and calling out an existing specification:
1. Saves time in that standards already exist that are “universally” accepted.
2. Suppliers already have these processes in place to economically produce these finishes.
3. The finish can be checked (verified by the specifier) using acceptable, in-place quality control procedures.

通常將用於工程材料的面漆或塗料
在（部分）文檔中使用 MIL 規範（MIL SPEC）進行標註
參考。 這樣做主要是因為大多數（常見）飾面已經標準化，並且要求現有規
範：

1.節省時間，因為已經存在“普遍”接受的標準。
2.供應商已具備這些流程，可以經濟地生產這些流程
完成。
3.可以使用可接受的原位檢查表面光潔度（由指定者驗證）
質量控製程序。

For example, a chemical film for aluminum may be called out to comply with a chemical film per MIL-C-5541.
An example of a callout for engineering documentation for a material and finish is:
・ Material: 16 Ga. (0.060) 1010 CRS (with CRS standing for cold rolled steel and the “1010” a shorthand for AISI M1010 Steel). AISI M1010 Steel is a low carbon, general purpose merchant quality steel, featuring economy plus formability and weldability.
・ Finish: Zinc plate clear chromate per QQ-Z-325. Class 2, Type II (with QQ-Z325 being a common MIL SPEC for zinc and the “class” and “type” specific choices for attributes such as minimum thickness).
One of the most extensive finishes for metals is paint. Painting can be very much a complicated process. Difficulties occur with:
・ Surface preparation
・ Color matching
・ Identification and control of defects
Ref. [9] is included as further information.
The material and finish callout on the engineering documentation should be unambiguously stated. It is a good idea to see how your company usually calls out these common materials and finishes, check with the supplier as to how the callout fits in with their processes, and what the quality control procedures for “guaranteeing” the material and finish will be handled by both at the supplier and at incoming (to your facility) inspections. Sometimes this is handled with a material/finish “certification” that is supplied to the incoming inspection by the supplier.

例如，鋁的化學膜可以被呼出以符合
符合 MIL-C-5541 的化學薄膜。
材料和表面處理的工程文檔標註示例
是：
・材料：16 Ga（0.060）1010 CRS（其中 CRS 代表冷軋鋼和
“ 1010”是 AISI M1010 鋼的簡寫）。 AISI M1010 鋼是一種低碳，具有通用商
業品質的鋼，具有經濟性和可成型性

和可焊性。
・表面處理：按照 QQ-Z-325 鍍鋅板清除鉻酸鹽。第 2 類，II 類（其中 QQ-Z325 是鋅的常見 MIL SPEC，特定於“類”和“類型”
選擇屬性（例如最小厚度）。
油漆是金屬最廣泛的飾面之一。繪畫可能非常多
一個複雜的過程。遇到困難的原因是：
・ 表面處理
・ 顏色匹配
・識別和控制缺陷
參考包含[9]作為更多信息。
工程文檔中的材料和完成標註應為
明確地說。最好看看您公司通常如何召集
這些常用材料和飾面，請與供應商聯繫，以了解標註的方式
符合他們的流程，“保證”材料和表面處理的質量控製程序將由供應商和進貨雙方處理
（到您的工廠）檢查。有時，這是由供應商提供給來料檢驗的材料/表面“證明”來處理的。

4.5 Punching andForming Metals

4.5 沖壓和成型金屬

The basic processes by which metals are punched, notched, formed, and bent has changed in recent years. Old fabrication techniques like (non-CNC) lathes, milling machines, and drill presses have been relegated to “garage shops” or “quick-turn” prototype shops (of the past). Contemporary fabrication is done on CNC (computerized numerical controlled) multi-axis machines or high-speed strippet punch
presses. Your CAD file is electronically transferred to the shop, the shop “converts” the file as input to their fabrication machine, and the machine creates the part (in specified quantity).
A strippet punch press takes a flat piece of stock and positions a rotating turret (pre-loaded) with round punches, rectangular punches (for cutting the periphery), and just about any shape punch (customized or already in the shop catalog), over that piece of stock. The table that the stock resides on moves in x and y, and the turret rotates to put the proper punch in place. A flat piece of metal can be completely punched out with a complex design in minutes. Specialized “punches” that punch and form louvers can also be programmed on the strippet. Tolerancing (which we

will expand upon in the following section) can be very tightly controlled with CNC as there is no "manual" setting of dials, stops, or machine feeds/speeds.
Multi-axis spindle machines are commonplace in today's fabrication environment. The term "5-axis" is typically referring to the ability of a CNC machine to move a part or a tool on five different axes at the same time. 3-axis machining centers move a part in 2 directions (X and Y), and the tool moves up and down (Z).
5-axis machining centers can rotate on two additional rotary axes (A and B) which help the cutting tool approach the part from all directions.
As with all fabrication techniques, the more the designer is familiar with the machine and machining process, the better the design will be Cost (Chpt4).
I've included a section on Sheet Metal Practices in Appendix. These show very common practices of bending and punching metal that sheet metal fabricators use and are commonly found in corporate drafting standard manuals.
金屬沖孔，開槽，成形和彎曲的基本過程包括
最近幾年發生了變化。舊的製造技術，例如（非 CNC）車床，銑削
機器和鑽床已降級為"車庫商店"或"快速轉彎"
原型商店（過去）。當代製造是在 CNC（計算機數控）多軸機床或高速沖床上完成的
印刷機。您的 CAD 文件已通過電子方式轉移到商店，商店"轉換"
文件作為其製造機器的輸入，然後機器創建零件（在
指定數量）。
脫模沖壓機取一塊扁平的原料並放置旋轉的轉塔
（預裝）圓形沖頭，矩形沖頭（用於切割周邊），
以及幾乎所有形狀的沖頭（已定製或已經在商店目錄中）
那張股票。股票所在的工作台在 x 和 y 中移動，而刀塔旋轉以放置適當的打孔器。一塊平坦的金屬可以完全
在幾分鐘內完成複雜的設計。打孔的專業"打孔器"
百葉窗也可以在剝離板上編程。寬容（我們
將在下一部分中進行擴展）可以通過 CNC 進行非常嚴格的控制
因為沒有"手動"設置轉盤，停止或機器進給/速度。
在當今的製造環境中，多軸主軸機床是司空見慣的。術語" 5 軸"通常是指 CNC 機床的能力
在五個不同的軸上同時移動零件或工具。 3 軸加工中心在 2 個方向（X 和 Y）上移動零件，刀具在上下（Z）上移動。
5 軸加工中心可以在另外兩個旋轉軸（A 和 B）上旋轉，
幫助切削工具從各個方向接近零件。
與所有製造技術一樣，設計師對
機器和加工過程中，設計的成本將更好（Chpt4）。

我在附錄中包含了有關鈑金實踐的部分。這些顯示非常
鈑金製造商使用的彎曲和沖壓金屬的常用做法
通常可以在公司起草標準手冊中找到。