Fastener Inspection

by Thomas Doppke

Making sure that what is in the box looks like the picture on the outside is a handy way to check out a product. But what about fasteners? They seldom come in a pictured box, or even labeled completely for that matter.

The order is placed with whatever company's Purchasing Department found with the best price and...! here they are: delivered to your door. What do you do next? Inspect them? How and what do you do?

Many companies, in a drive to reduce expenses have elected to go with systems where the vendor is responsible for the quality of his own parts. Similar to playing Russian Roulette, this is a potential shot to the head. While most companies do exhibit excellent quality, the constant push for the cheapest parts allows sub-standard and questionable manufacturers access to the open market. Even the best of companies, when pushed by schedules (and their customers) may close an eye to parts that are not quite 100%. For your parts, a look, however slight, is better than a blind acceptance.

The level of inspection varies with many factors; such as local procedures, cost, available manpower and equipment to check parts, being just a few items considered. Many quality control and inspection plans are listed in industrial literature, military standards, society standards, and company specifications. How many pieces and what is to be checked have all been calculated by statistical engineers. The plans vary as few of these engineers can never quite agree on a number! Assuming that there is some sort of standard inspection plan in place at your company (hopefully), let's look at what items are important.

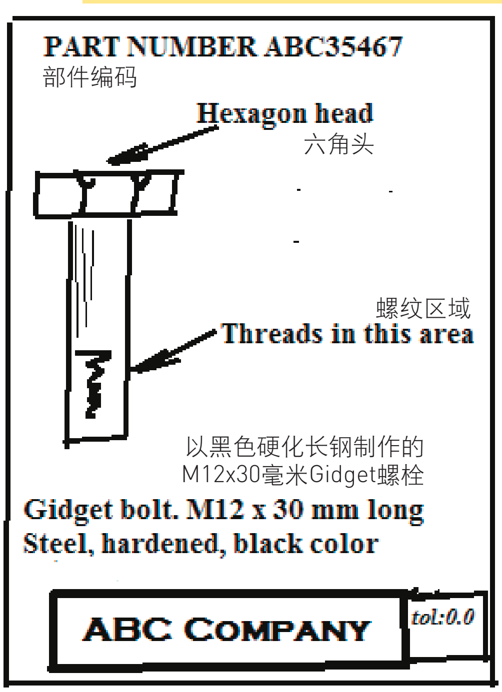
While a part can be found non-conforming, its documentation should be first examined to validate your rejection. One of the greatest faults today is that parts are ordered with insufficient information. A famous example is an order of washers which had the center hole punched off-center in numerous pieces. While the order stated simply outside diameter, inside diameter and thickness, it did not locate the hole at the center. Easily overlooked in modern industrial manufacturing with progressive stamping dies; the order was placed with an inexpensive third world operation which punched the interior holes as a secondary, off-line, hand operation! While this is an extreme case, the rise of low cost third world manufactured product has penetrated all major markets. The illustration shows an example of the type of blueprint often sent out with an order.

While this one is a fictitious and extreme, humorous drawing it is not too far off from actual ones that I have seen. A reliable and qualified maker would reject this at first sight but less scrupulous distributors would certainly fill this. Guess what you'll get? I can't imagine.

Following the confirmation of what was actually ordered (as the supplier will plead that he has produced what your company asked for, and probably not a dimension or facet more) let's examine the parts. One of the most common fastener defects is in the threads. The threads are made by spinning the blank between two plates which form the threads

紧固件检验

文 / Thomas Doppke



▲ Fig. 1 / 图1

检验产品是确保包装盒内货品看起来像包装盒图示的一种简单的方法。但是，紧固件也是这样吗？它们买来的时后很少包装在有图片的盒内，也很少有完整清楚的标示以供查验。

采购部认为哪一家厂商价格最好，或者其他什么理由，订单就下给哪一家！反正，东西在这里，直接送到你门口。下一步，你该怎么办？该检验吧？问题是，怎么检验？还有，要检验什么？

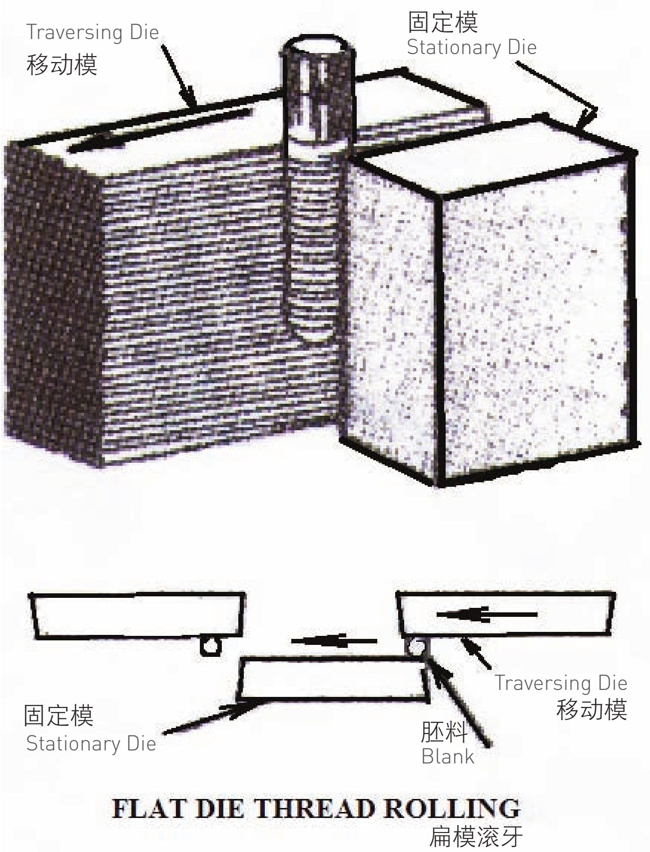
许多企业，为了减少成本，选择使用供应商负责自家品质的产品系统。这样的决定，若是拿俄罗斯轮盘作比喻，有头部中弹的潜在风险。大多数公司虽然都展现品质卓越的形象，但是不断要求产品最低廉的趋势却使得未达标准和品质有疑虑的厂商得以进入开放的市场。即使最优良厂商，迫于时间表(以及客户需求)，对于品质不是百分百的部件，也可能睁一只眼，闭一只眼。看一看你所使用的部件，即使只是稍微看一眼，都比盲目接受来得好些。

as they are pushed through and twist the blank (there are other methods but the idea is the same).

A quality thread requires, obviously, a quality rolling die. Poorly aligned dies are the cause of many thread errors. A slight offset between the two die plates will produce a thread with a "lead error". A normal thread assembles with a small clearance on its backside and rests against the tightened side as the illustration shows. The plate offset error produces a thread that fits fine when measured one thread to its mate but slowly uses up the clearance as multiple threads engage. The result is that the threads will jam up against a mating thread somewhere down the line. Not readily observable with a single thread gage, it is a cumulative type error that can jam assembly if threaded in more than a few threads (usually two to three diameters will cause a jam).

Alignment problems between the two plates can produce drunken threads (wavy thread form). The misalignment causes a non-helical (discontinuous) thread. As with most of the thread errors discussed here, there is no fix. The solution is to scrap the lot or send the parts back as failed material. Unsuspecting buyers beware! Those companies without an inspection program or Quality Control department may receive these 'bargain' parts.

Tapered threads (the blank is squeezed harder at one end than the other, producing a tapered threaded



▲ Fig. 2 / 图2

检验的程度会随考量因素而不同；例如，地方所规范的检验程序、检验成本、检验部件、现有人力和设备，这些是考量因素其中几项。许多品质管制和检验计划在产业文献、军方标准、专业学会标准以及公司产品规格都有明确规范。至于检验几支部件、检测哪些项目，统计工程师都已计算出来。这些品管检验计划却各不相同，因为，这些工程师很少针对同一个数字表示完全同意！假设你的公司目前有一套标准的检验计划在实施，我们来看看哪些项目比较重要。

一支部件可能检验出不合格，但是，检验纪录文件应该首先审查，以便证实这个不合格判定的有效性。今天一个最大的缺点是，部件下订单时，往往附带资料不足。有个着名的垫圈订单案例，数不清的垫圈凿出偏心的中心孔。订单只指定外径、内径和厚度，却没有指示中心孔的中心位置。这对于现代产业多使用进阶式冲模制程很容易被忽略；偏偏订单又下给第三世界一家廉价工厂，结果把内孔冲压当成次要制程，可以在生产线外以手工进行的作业！虽然这是极端例子，第三世界低成本制品在市场兴起已经渗透全球主要市场。图1所示为订单常见附图类型的一个例子。

虽然这样的工程图是虚构、极端、幽默的例子，但是和我所看过实际上存在的相去不远。比较可靠合格的制造商看到这工程图一定不会采用，但是比较不严谨的经销商就会拿这附图去充数。你猜猜结果是什么？这个我不敢想像。

确认订单所指定之后，让我们来检查部件本身(因为供应商会向你恳求，说他按照你们公司所要求的去生产，可能还说尺寸不会多一吋，外观不会多一面)。最常见紧固件不良项目之一就是螺纹。螺纹的制作是让坯料在两片板材之间转动，两片板材向螺杆挤压，扭动坯料的同时即形成螺纹，当然还有其它方法，但概念是一样的。

很明显的，若要螺纹品质好，就必须有品质好的滚轧模具。模具对准不良是许多螺纹错误的原因。两个模板之间彼此一点微小的抵销或补偿会产生出"前导错误"的螺纹。一个正常螺纹在组装时，背向面的间隙小，并且螺纹顶着紧固面，如图2所示。板片平衡错误所产生的螺纹，若只检测单一螺纹，其偶合度尚可，但随着多数个螺纹接合，间隙慢慢用尽。结果未来某个时间点，偶合螺纹上会出现螺纹打结卡住。这是一种累积的错误类型，以单一螺纹量规不易观察，如果一次滚轧多数螺纹，会造成装配阻塞(一般两到三个直径就会产生阻塞)。

两个模板之间对准的问题可能产生俗称的「酒醉」螺纹(波浪状螺纹形式)。对准不良导致非螺旋(不连续)螺纹。与这里讨论大多数的螺纹错误一样，同样无法修复。解决的办法就是整批丢掉，或是视为不良品退回。不知情的买家要小心！没有检验程序或品管部的公司有可能接收这些"便宜货"。

锥形螺纹(坯料挤压一端重，另一端轻，产生锥形螺纹部位)。就像你在两手之间滚动一块粘土，坯料在模板之间滚轧出螺纹。受力不均将导致一端或另一端被挤压得重一些，结果会产生出一个锥形部件。将螺纹量规走过整个螺纹部位长度，你应该就可以检验出是否有这种故障不良。

螺纹尺寸过小/过大是坯料在两个模板之间转动时所受的挤压强度有差异，或是模板磨损所致。

螺纹滚轧模板价格昂贵，而且制造商总是希望在更换模板之前，尽可能制作多一些部件。磨损的模板制造不出正确尺寸的部件。螺旋角度错误，螺纹截断，甚至成形不良碎裂，以及模具拉扯所造成的龟裂都可能发生。

最后但是比较罕见的错误是紧固件表面出现一点平坦部位。这是受损坯料所引起，通常来自有刻痕或是有凹陷的钢铁线材，可能递延到螺纹成形制程，在螺纹上留下椭圆或平坦的一点。大批量桶装出货也让部件彼此堆迭，使螺纹产生刻痕。除了来自线材，刻痕也可能发生在部件生产过程中几个时间点。将桶装部件从螺纹成形制程搬运到热处理制程时尤其容易造成刻痕，因为此时部件尚未硬化处理。还有，桶子倾倒到热处理高温炉的输送带上，运往电镀工厂(以及运回)。最后，大桶分装到小包装盒(如果不是直接整桶大批量出货)。

以一个样品检验不可能找到所有的不良缺陷，无论样本数多少；但是，如果部件是持续被购买的商品，就有找到缺陷不良的机率，只是时间早晚而已。如果整批次制造不良，很快发现不良品的机率就很大。有一家实验室为一家大型汽车公司测试所有批次的紧固件，而且进行好几年。样品数大约15件；5件进行硬度测试，5件检查尺寸，另5件拉伸拉力测试。这些部件虽然来自顶级厂商设有自家内部品管系统，所有批次当中却发现15%不良！

portion). Like rolling a piece of clay between your hands, the blank is thread rolled between the die plates. Uneven pressure will result in one end or the other being squeezed harder and a tapered part will result. Running the thread gage the entire threaded length should allow you to discover if this fault exists.

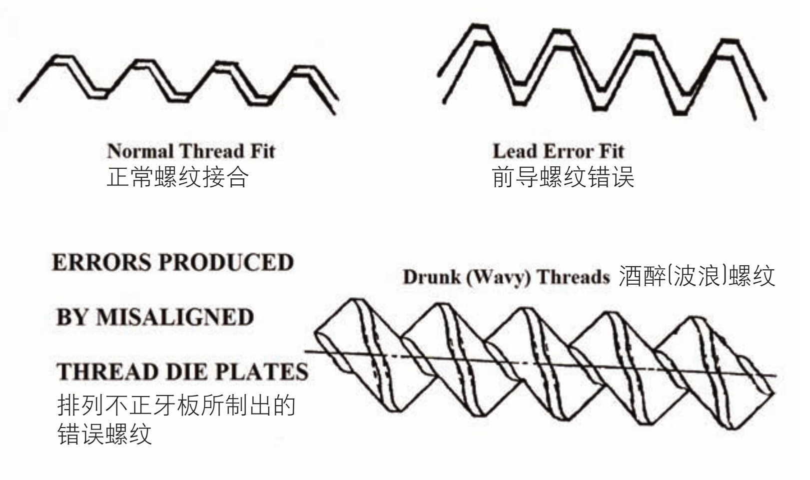
Undersized/oversized threads result from either a variation in the amount of squeeze when spinning the blank between the two plates or from worn die plates.

Thread rolling die plates are expensive and manufacturers want as many parts as possible from the plates before replacement. A set of worn die plates will not produce a correctly dimensioned part. Wrong angles, truncated threads and even malformed tears and cracks caused by pulling of the dies may result.

A final but rare error is that of a flat spot on the fastener. Caused from a damaged blank (often carried over from a nicked or dented coil), it may carry over to the threading, yielding an oval or flat spot on the threads. Shipping large quantities in bins also allows the parts to bank against each other, nicking threads as well. Nicking can occur at several points in the part manufacture besides coil nicks. Moving the parts in bins from threading to heat treat is especially contributable as the parts are not hardened. Dumping the bins onto furnace conveyers, shipping to the plating operation (and back again). And finally from bin to boxing (if not shipped directly in bins).

It is not possible to find all the defects with a sample inspection, regardless of sample size, but if the part is a continuously purchased item the probability is that a defect will be found sooner or later. If the entire lot is poorly made the odds are great that wrong parts will be found quickly. A test laboratory site for a large automotive company tested all lots of fasteners for several years. A sample size of about 15 pieces was used; five pieces were hardness tested, five dimensional checked and five tensile pulled. Although these were parts from top line companies with their own internal quality programs about 15% of the lots were found defective!

The usual inspection method for threads is a Go and No-Go ring gage. The gages measure parts that are within the dimensional limits of the thread specification. Easy to use, they are slightly better than single point gages which may not catch cumulative errors (lead, wavy threads, etc.) The gages measure



▲ Fig. 3 / 图3

螺纹检测方法常见的是一种判定合格和不合格的环状量规。环状量规可测量螺纹规格尺寸范围内的部件。因为使用容易，环状量规比单点量规好一些，单点量规可能无法测出累积性不良(如前导螺纹、波浪状螺纹等)。这种量规测量紧固件尺寸的上限和下限(太小则进得了不合格的量规，太大则进不了合格的量规)。由于易于使用而且价格便宜，环状量规可以找出前导螺纹错误、波浪状螺纹、不正确尺寸、锥状螺纹，以及有刻痕和破损的螺纹。紧固件虽然是大多数组装件和组装作业最便

the upper and lower limits of the fastener dimensions (too small will enter a No-Go gage, too large will not enter a Go gage). Easy to use and inexpensive, they can sort out lead errors, drunken threads, incorrect dimensions, taper, and nicked and damaged threads. While fasteners are the cheapest part of most assemblies and assembly operations, a nicked thread will not assemble easily and to the proper torque (assembly failure).Too small a part will not be tightened to the specified loading, leading to a failure down the road.

The next major defect commonly found in fasteners is that of incorrect, poor or even missing heat treatment. The fastener industry has had a system of marking, for years, to identify the relative hardness of fasteners according to various specifications. The sale and distribution of mismarked fasteners has been a great problem throughout the industry. Unscrupulous manufacturers have shipped mismarked and even un-heatreated parts with hardened level head markings. This problem is especially prevalent with smaller lots and material destined to smaller users whose inspection systems are usually non-existent. There is no normal reason that softer parts should be shipped in place of correctly processed ones beyond sheer negligence and criminality.

The selection of the proper grade of steel for the finished part is not especially difficult. Decades of experience, industrial groups, governmental authorities, and numerous companies have resolved the question of what to use. However, for a fastener to be properly hardened it must be of the proper grade of steel. Higher hardness parts require steel which is more expensive than low hardness ones. High carbon and alloy steels are used for high strength fasteners. Low carbon steel may be heat treated or left un-heat treated, depending upon the strength specified. Obviously, substituting a cheaper steel and passing it off as a higher carbon or alloy part is a financial plus for the unscrupulous manufacturer. The global community has adopted a set of notations, usually stamped or marked upon the bolt heads, to identify the differences, avoiding accidental mix-ups.

But even with the proper material a poor heat treatment will not produce a perfect part. Too high a temperature will yield parts that are softer than specified (low tensile and yielding at low torque will result); too low furnace conditions will give parts at the high end or overly hard (spotty hardness and varying tensile strength). Other conditions inside the heat treat furnace may cause other defects. Poorly manufactured wire (again, low cost material) may have laps, cracks, seams and inclusions internally from the smelting and rolling processes. These may open up during one or another of the treating steps (heat, quench in proper medium [oil, water, etc.], and temper to correct hardness). To avoid depleting the surface of carbon (the hardness of the parts is a result of the carbon content of the part) extra carbon is added to the furnace atmosphere to avoid burning off surface carbon (decarburization). Again, too much will produce a very hard, thin layer which may crack under loading while too little will 'decarb' the surface and reduce the strength of the formed threads to the same as a soft steel part.

宜的部件，有刻痕的螺纹却无法轻易组装，也无法达到适当扭矩(组装件功能失常)。部件太小则无法紧固到所指定的荷载力，导致日后使用期间出现功能失常。

紧固件另外一个常见的缺陷不良主要是热处理不正确、不良，甚至于从缺。紧固件产业多年来有一套标记系统，可根据各种规格来辨识紧固件的相对硬度。标示错误的紧固件到处销售配送已经为整个产业带来严重问题。不肖的制造厂商已经把标示错误甚至未经热处理的部件，打印上硬化等级的头部标记，充当正级品出货。这问题在小批量和小宗物料使用者的订单尤为普遍，因为这种使用者通常不具有检测系统。没有任何正常理由可以允许未经硬化处理较软的部件当作正当处理部件来出货，这种作法，纯粹就是疏忽和犯罪行为，别无其他理由。

选用适合等级的钢材来制作部件并不困难。虽然以数十年经验，工业团体、政府机构以及众多企业厂商早已解决选用什么的问题。紧固件要适当硬化处理就必须使用正确等级的钢材。相较于低硬度部件，高硬度部件需要比较昂贵的钢材。高碳钢和合金钢用于高强度紧固件。低碳钢可作热处理，或者保留不作，视所指定强度而定。制作部件改用便宜钢材，却当作高碳钢或合金钢制品销售，这对于不肖制造商当然明显是一本万利，财务上是绝对利多的作法。国际社会已建立一套标准标示系统，通常打印或标记在螺栓头部，用以识别，以免意外错用。

This "decarb" layer will strip easily in assembly, causing failure of the joint. The attached photo shows the result of a decarb layer on screws that were assembled to their normal torque value.

Decarb is best checked by microscope (expensive and technical) but it can be determined by taking a surface hardness reading. The hardness machines in standard use today are capable of taking readings with various weights to measure the hardness at various levels. A low weight will show surface hardness (15N, etc.) while the standard "C" readings suffice for basic structure hardness. The easiest inspection for decarb is a hardness test. The machine is relatively inexpensive and easy to operate even with unskilled labor. A further test, a tensile pull, will show if the part is made of the right material and heat treated correctly. It is possible to have a correct hardness on a lower strength material; the tensile pull will define the parts adherence to the specification exactly. The tensile test is, unfortunately, expensive and requires either a test laboratory or an outside testing facility and is used in cases of dispute. A microscopic examination is also a final arbitration solution.

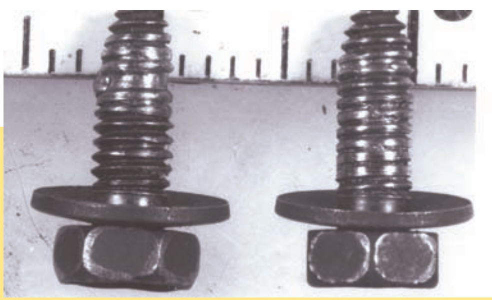
While there are several other defects that occur in manufacturing, they are, for the most part, not usually found and almost never detected with low tech inspection equipment. Many larger companies now employ automatic inspection equipment as a look at the ads in this magazine will show. These types of equipment can sort for specific defects at very high rates where a very high level of conformance is required (military, aerospace, critical applications). It was determined that even an astute Inspector, after working several hours, is only about 75% effective in finding defects while the "state of the art" machines run 100%, 24/7.

No one likes rust or corrosion. For that reason many parts are coated with a finish to retard corrosion. Wrong finish, or rather, insufficient finish, is a major after-market complaint. Unfortunately there is no simple or easy way to check for this. Unless the part is ordered with a black, gold or silver color finish and is not that color visibly, the usual check is a salt spray test. Some relief can be had using a plating thickness meter which measures the thickness of the coating but the test is tricky and open to dispute (where it taken, conditions, etc.)

Internally threaded product (nuts) are a further problem as few grades are marked and hardness and gaging are about the only quick inspection methods that can be performed with minimal equipment at out 'mini-inspection' station.

Bolts are usually cleaned (a light sanding) on one of the hexagon head flats and the opposite side. This removed any surface dirt. A low reading may indicate decarb and a surface reading should also be taken. The hardness value should not be below the specified value. A nut is usually tested on a nut face, if possible, as this surface will represent the true core hardness. The hex face is tested for decarb, if suspected. Remember, the decarb test is only for heat treated parts. The No-Go and Go gages are threaded into nuts and the bolts are threaded into the gages.

The cost of inspection has been a sore point between the financial and plant personnel. Weighting the cost of employees to pull samples and inspect, storage of 'in process' material and 'reject hold' material, scheduling, etc., deflates the bottom line of many companies. However, what is the cost of a reject? Low cost items may just generate a grumpy customer who may be mad about the fact that the part broke the first time he used it but high cost items may incite lawsuits, loss of customers who will never buy your product again (consider an automobile's cost) and a loss of your company's reputation.



▲Fig. 4 / 图4

不过，即使材料选用合适，热处理不良也无法产出完美的部件。温度过高，产出的部件硬度会低于指定所需(抗拉强度低，导致低扭矩即出现降伏)，炉体温度状况过低，则部件硬度处在上限高端或是硬化过度(硬度参差不齐，并且拉伸强度差异)。热处理炉内其他状况可能引起其他不良情形。制造不良的线材(这又是廉价材料)可能含带冶炼和滚轧制程留下的圈状痕、裂缝、接缝以及所夹带的杂质。这些情形可能在热处理其中某一个或另一个阶段开始形成，(例如：加热、在适当介质[油，水等]中淬火急冷，以及回火到正确硬度)。为了避免消耗部件表面的碳(部件的硬度是部件含碳的结果)，炉内气氛需另添加碳元素，以避免表面碳烧掉(脱碳)。同样的，含碳过多将产生既硬又薄但受荷载易龟裂的表层，含碳过少则表面"脱碳"，使成形螺纹强度减少到等同软质钢制部件。

这种"脱碳"表层在装配时很容易剥离，造成接合部位功能丧失。图4表示某一螺丝以其正常扭矩值组装而有表层脱碳的结果。

脱碳最好借由显微镜(昂贵而技术高的设备)检查，但是读取表面硬度值也可测出。现在使用的标准硬度量测仪

器能够读取不同重量的硬度值，并以等级划分。低度重量会显示表面硬度(15N，等等)，而标准“C”等级的硬度值足够作为基本结构的硬度。最简单的脱碳检验是一种硬度测试。这种测试仪器相对便宜，即使不熟练的工人也操作简便。进一步的拉伸拉力测试显示部件制作材料是否正确，以及热处理是否适当。材料有可能硬度正确但强度不足；拉伸拉力测试可测出部件是否遵守规范。不幸的是，拉伸测试很昂贵，需要由测试实验室或外部测试设施，只用于有纷争的情况。显微镜检测也是最后仲裁解决。

虽然发生在制作过程的不良情形还有其他几种，大多数情况都不常发现，而且几乎不曾以低技术检测设备测到。许多大公司现在采用自动检测设备，有关这一点，看看本杂志广告就知道。这些类型的设备可以非常高的速率，在规范符合度要求相当高的应用(军事、航空、关键性应用)测出特定的不良缺陷。测试结果显示，即使是很精明的检验员，几个小时工作下来，发现不良品的工作有效程度只有大约75%，而“最先进的”机器是100%，连续7天24小时运作。

没有人喜欢生锈或腐蚀。出于这个理由，许多部件都有表面涂装以延缓腐蚀。错误的表面涂装，或者说，涂装不足是销售后主要的客户抱怨。不幸的是，没有简单容易的方法可用来检验这一点。除非订单的部件具有黑色、金黄色或银色的表面涂装，而视觉上看来不是那个颜色，通常的检查是盐水喷雾试验。使用测量电镀层厚度的涂层厚度量规就可安心，但这个测试有些棘手，目前尚有争议(测量部位、条件等)。

内螺纹产品(螺帽)是个比较复杂的问题，因为许多等级都没有标记，唯一可以使用最少设备，在「迷你检查站」快速进行检验的大概只有硬度测量法。

螺栓清洁的时候(轻度磨砂)，通常立于六角头部平坦面其中之一的表面上，这样就可除去表面上任何污物。所测得读取值若是低，可能表示有脱碳现象，必须进一步测量表面硬度值。硬度值不应低于规范值。螺帽测试部位通常尽可能是螺帽表面，因为该表面代表真正核心硬度。如果有疑问，六角头的正面是脱碳测试的部位。记住，脱碳测试仅适用于热处理部件。合格/不合格量规螺纹必须旋入螺帽，而螺栓螺纹必须旋入量规。

检验成本一直是财务和厂务人员之间痛苦的一点。员工去取样和检验的成本、储存「过程中」物料的成本、「退回或保留」材料的成本、调度排程等等成本，衡量比较这些成本常常让公司的底线难以维护。但是，所谓退回成本是什么？成本低的货品可能带来客户抱怨，这客户可能生气第一次使用那支部件，东西就坏了，但是成本高的项目可能是招来诉讼、客户流失，因为不再购买你的产品，(想想一部汽车的成本)以及你的公司声誉的损失。