

# Workmanship - Troubleshooting Common Fastener Defects



Created for:  
Industrial Fastener Institute  
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For further technical  
information and assistance  
contact [techinfo@indfast.org](mailto:techinfo@indfast.org)

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**The startling fact is that experts project upwards of 95% of fastener failures are the result of poor selection or improper installation.**

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## Why do Fasteners Fail?

- 

Poor fastener selection for the application

  - Not strong enough to withstand service loading
  - Wrong material for service environment
- 

Loss of tension during operation:

  - Joint relaxation
  - Joint creep
  - Thermal expansion and contraction
- 

Fastener not properly pre-loaded or installed
- 


**Manufacturing flaws or surface discontinuities**
- 

Abuse and mis-use

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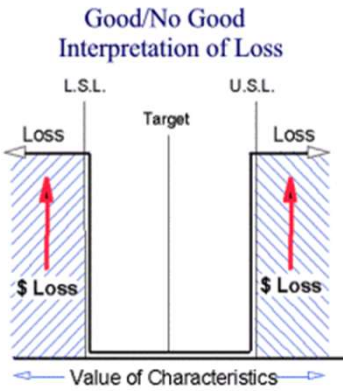
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## Old Way of thinking about Quality?

Good/No Good Interpretation of Loss




← Value of Characteristics →

Any part "In- Specification" is equally good.


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## Old Way of Executing Quality




- Mistakes/errors were expected
- Quality was “inspected in” after the fact


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## Taguchi Loss Function



Renown Japanese Quality/Business Expert, Genichi Taguchi, proposed: Contrary to traditional thought that said a customer only became dissatisfied when a part was out of specification, Taguchi proposed that the value to the customer decreased exponentially the further the product deviated from the target.

Figure 5

Good/No Good Interpretation of Loss

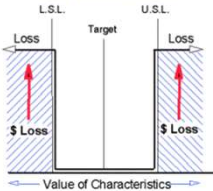
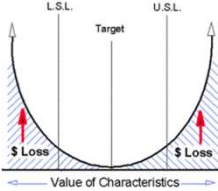


Figure 6

Taguchi - Continuous Interpretation of Loss



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## A New Way of Thinking About Quality

There is one point of ideal quality/satisfaction and as we move away from it, the quality/satisfaction decreases and thus the way we actually value the product decreases



LSL

USL

Least Dissatisfaction  
(Most Satisfied)

Day 1 Day 3 Day 5 Day 7 Day 9

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## “New” Way of Executing Quality



- Quality must come from a stable and consistent process
- Variation is the “enemy”
- Improvement drives all activities
- Quality cannot be “inspected in”
- “Zero Defects”

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 Expanding our Concept of Manufacturing Related Fastener Failure to the Quality of our Product

**Traditional Philosophy:**  
The only failed parts are those that actually break



**Expanded Philosophy:**  
Any part that fails to meet the customer's expectations, prevent assembly, breaks at installation, breaks in service, or prevents usage is a failed part.

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 Why is Good Quality Important?

**Quality= meeting the needs and expectations of customers**

**Excellence= being truly the best at something**


- Poor Quality parts may not work or break causing injury or death
- Poor Quality costs your company
  - Money
  - **Reputation**



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## What is the Cost of Poor Quality?

- What are the true costs of poor quality?
  - Unfortunately, most companies lose more than they expect to “poor quality”
  - Just do the math- if your cost of poor quality is just 1% of sales, then for every 1 Million \$ of sales, \$10,000 is wasted
  - Most companies have a Cost of Poor Quality in the 5-30% range<sup>1</sup>
  - Imagine your company is ~\$50,000,000 in sales. For every 1% of Poor Quality, you **WASTE** \$500,000!




**If your company is operating at world-class levels of 5%- it means you spend \$2,500,000 a year on Poor Quality!**

<sup>1</sup> Shellye Archembeau, What is your Company's Cost of Poor Quality, August 2004

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## What Makes up the Cost of Poor Quality

- From the Plant
  - Scrap
  - Rework
  - Time spent dispositioning material
  - Time spend purchasing new or extra material
  - Re-inspection
  - Re-testing
  - Rework of tooling
  - Added operations
  - Extra capacity and inventory to address lower process yields
  - Problem investigation
  - Overtime
  - Scheduling changes
- From the Customer
  - Time to process complaints
  - Returns
  - Warranty Claims
  - Recalls
  - Field service costs
  - Premium freight/extra shipping
  - Late delivery penalties
- Intangible Costs
  - Customer dissatisfaction
  - Loss of reputation
  - Inefficient processes


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### What do you think of each of these fasteners?



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### What is “Good” Workmanship




This question might be best answered by thinking about “Bad” workmanship- we all seem to recognize that when we see it.


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## What is “Good” Workmanship





What can we say?- “Good” parts...

- Look good- they do not have surface defects, appear well constructed, and look like the person who made them cared about what they were doing.
- Are free from blemishes, obvious errors, and small, sometimes hard to notice errors and defects.
- Have obviously been made by someone that cares and takes pride in their work.

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Why does workmanship matter?

What impact does bad workmanship have on us?

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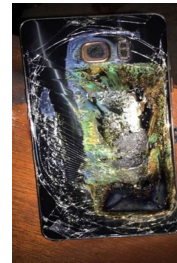
## It will Sully Your Reputation

- That company ...
  - ... caused us to work overtime last week...
  - ... always seems to give us bad parts...
  - ... is a lousy fastener company. Why do we keep doing business with them?
  - ... must be a bunch of stooges..



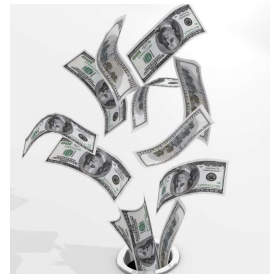
### A story:

Remember in 2016 when Samsung Note 7 (premium cell phone) batteries started exploding. They had 92 incidents after which they performed a full international recall to the tune of \$5.3 BILLION. That, however, is only the tip of the iceberg, they discontinued sales after 2 months on the market losing an estimated 19 million future sales or about \$17 billion. None of that accounts for the hit to Samsung's reputation. As one UK lawyer put it, "The Note 7 unit is forever going to be tarnished and the danger is that the brand becomes irretrievably damaged as well."



## It will Cost You Money

- What do you have to do to make it right with your customer?
  - Sorting
  - Scrap
  - Expedited Freight/Shipments
  - Overtime
  - Recall/Warranty Claims

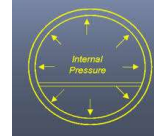




## It could put parts at risk

### An Illustration:

For aircraft to fly high but keep the passengers comfortable, the cabin must be pressurized. When this happens forces push out on the fuselage. When the aircraft lands the fuselage goes back to normal. This creates a cyclic loading effect and puts the aircraft and its components at a risk for fatigue failure. Fasteners that have surface imperfections and flaws are particularly vulnerable. Aircraft fasteners, therefore, often are made to higher levels of workmanship than their industrial counterparts.



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## Workmanship Requirements in Aerospace and Internal Engine Fasteners

- General Appearance
  - No obvious surface damage
  - No burrs
  - No geometric deformities
- Geometric Form
  - End condition
  - Shaved/Trimmed Heads rather than Free Form
  - Trimmed Hex heads
- Demand for Class 3 Threads
- No Laps or Other Discontinuities Allowed

- \* NDT Testing is Common
- \* Rolling Threads After Heat Treatment Common
- \* Fillet Rolling is Common
- \* Commonly Use Seam and Decarb Free Wire
- \* Use Double or Triple Vacuum Melted material



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## What do you have to get right?

You must know your customer's needs so that you may satisfy them.

- Is fatigue an issue?
- No visible defects (folds, voids, cracks, or burrs) on parts
- No thread laps
- Properly heat treated
- No plating or coating anomalies
- No handling damage
- Good grain flow



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## A Story About Manufacturing Defects



Porsche 918 Spyder  
 June 2015  
 NHTSA Recall NO: 14V-816  
 Size of Recall: 39

Porsche reported the reason for recall: "Due to the manufacturing error the durability of these components (said to be fasteners) installed in the affected vehicles cannot be guaranteed."

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**A Story About Manufacturing Defects**

Little Giant Brand  
Multipurpose ladders

March 2017

Voluntary Consumer  
Product Recall

Size of Recall: ~37000

Wing Enterprises reported the reason for recall: “locking pin/rung fasteners may fail posing a fall hazard to consumers”

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**A Story About Manufacturing Defects**

Ford Motor Company-

2014 F Series Pick-up,  
2014 E Series Van, 2014-  
2015 Ford Escape, and  
2015 Lincoln MKC

July 2017

NHTSA Recall No: 17V-  
472

Size of Recall: 117000



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## A Story About Manufacturing Defects

- Description of Recall:
  - “ Improperly tempered bolts may have been used to install certain seats, seatbacks, seatbelt buckles, or seatbelt anchors on these vehicles”
- Chronology of Investigation:
  - February 16, 2017- A Ford employee reported the RH, 2<sup>nd</sup> Row seatbelt anchor bolt had fractured in his 2015 MKC.
  - Ford Central Labs investigated the broken screw and found the failure to be intergranular in nature and initiated from a thread lap. Hardness investigation showed the surface hardness to be harder than specification of 340-370 HV.
  - Subsequent investigation determined that the Tier 2 heat treater experienced a power outage on April 17, 2014, as they were processing a portion of the lot of parts. This resulted in an improper temper.
  - 154,000 pieces were shipped from this lot to various Ford Assembly plants resulting in the recall action

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## A Story About Manufacturing Defects



Example taken from, “ The Role of Manufacturing Defects in Munition Component Failures” Published by US Army Research Lab Weapons and materials Research Directorate

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## A Story About Manufacturing Defects

- Component: LAU-7 Missile Launcher Attachment Bolts
- Description:
  - (2) attachment bolts were found broken at Oceana, VA during pre-flight inspection
  - Parts were inadvertently carburized during heat treatment
    - Contributed to SCC brought on by localized corrosion
  - Parts were also screw machined and not formed as required, so they did not have the requisite strength



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## A Story About Manufacturing Defects

- Lendenhall Building- London
- 2014- Experiencing Rod Failures
- Conclusion was that rods failed by environmental hydrogen embrittlement contributed to by multiple manufacturing defects
  - Non-uniform heat treating and hardness
  - Cracks in threads originating from pits, laps, and absence of root radii



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**Introduction to Common Fastener Defects**



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**Understanding the Manufacturing Process**

- To troubleshoot common fastener quality problems, one must become an expert in the manufacturing process
  - Understand how raw material is produced
  - Understand one's internal processes
  - Understand external vendor processes



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## What we will look at


- Categories
  - Raw materials
  - Forming
  - Threading
  - Secondary Operations
  - Handling
  - Heat Treating
  - Plating and Coating



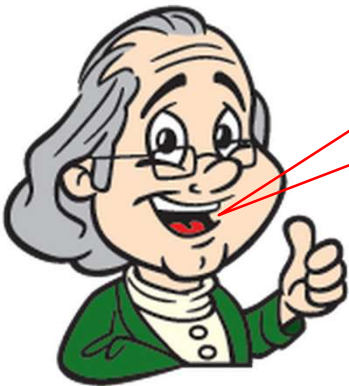
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## Detection and Prevention




**An ounce of prevention is worth a pound of cure.**

With each problem we will try to explore the ability to detect the problem and what is necessary to prevent it.

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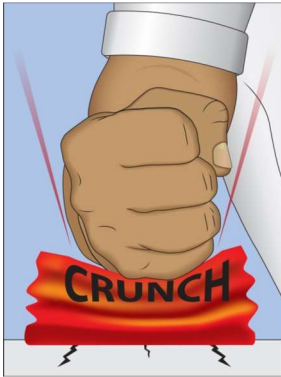


**Part 1:  
Problems Coming From Raw  
Material**

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**Refresher- Cold Heading Quality Wire  
and Rod**

Question: In simple terms, what basically happens in a cold header?

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 **Refresher- Cold Heading Quality Wire and Rod**

Question: Knowing the extreme conditions the raw material is exposed to in the cold heading process, what kind of things might we need the material to do?

**It Must:**

- Form without cracking
- Form without breaking tools
- Not stick in or to the tools
- Not have minor surface defects
- Be consistent in size and shape



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 **Refresher- Cold Heading Quality Wire and Rod**

- Cold Heading requires consistent, reliable performance of raw material
  - CHQ= Cold Heading Quality
  - Recess Quality
  - Aerospace Quality
  - Seam and Decarb Free
- Rod= End Product of Hot Rolling Mill
  - Dimensional
  - Surface
  - Microstructure
- Wire= End Product of Cold Drawing
  - Dimensional
  - Surface
  - Microstructure



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 **Refresher- Cold Heading Quality Wire and Rod**

- Manufacturing Strategies
  - Direct Feed
    - Wire is fed directly into header (Ex. SAIP steel wire)
    - Bar is cut and loaded directly into press or header
    - Bar is fed directly into screw machine
  - Draw First
    - Wire is fed into header AFTER going through a light drawing process
    - Ex: SAFS steel wire, A286, work-hardening steels





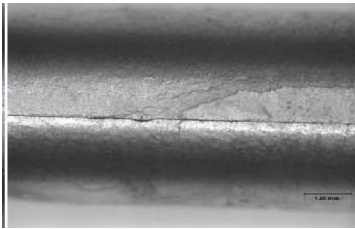
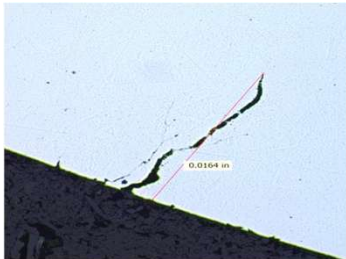
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 **Common Mill Problems- Seams**

- Seams are hot mill or casting related non-conformities
- Causes
  - A hot mill scratch or hot crack that opens and then is rolled shut.
  - Solidification related surface anomaly that becomes part of the wire surface.
  - Some oxidation product is generally associated with a seam.

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## Common Mill Problems-Seams

- Severity of seams
  - The degree to which a seam will affect a part largely depends on the part.
  - A seam/scratch as shallow as 0.0003" has caused splits in a pan head with a six-lobe recess.



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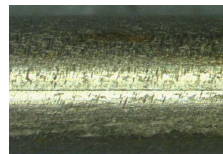


## Common Mill Problems-Seams

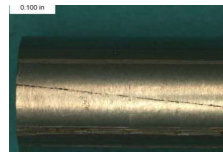
- Appearance
  - Appear on surface
  - Longitudinally-oriented
  - In cross-section: normal towards surface
  - Can be continuous or intermittent
  - Can be longitudinal or spiral in nature



Cross-section of Seam



Longitudinal Oriented Seam



Spiral Oriented Seam

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## Common Mill Problems - Seams


- Prevention:
  - Mills will grind surface defects from billets prior to hot rolling
  - Mills employ Eddy Current or other technologies during hot rolling to audit the surface quality during rolling
  - Mills offer “Seam and Decarb” free wire to customers
    - “Seam free” = wire rod surface is removed to a depth sufficient to remove non-desirable surface anomalies.
    - Non-seam free wire or rod - a seam or scratch with depth up to 1% of the wire or rod diameter is allowable.




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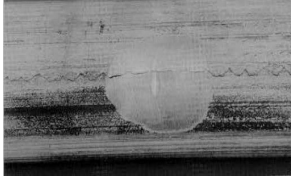
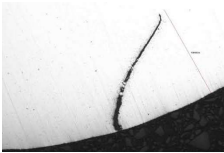
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## Common Mill Problems- Laps


- Laps are hot mill related non-conformities
- Causes
  - Overfill on a hot rolling pass that is rolled back over the rod surface
- Appearance
  - Often has a “double-track” appearance.
  - In cross-section: At an angle other than normal to the axis

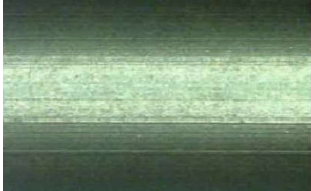
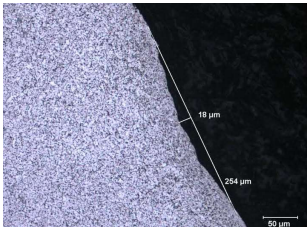
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 **Common Mill Problems- Scratches/Scoring**


- Scratches are non-conformities that can occur in either the hot mill or cold drawing process
- Causes
  - Caused by the wire or wire rod rubbing against a sharp surface
    - Hot mill guides or laying head.
    - Die loading.
    - Any metal-on-metal contact with sufficient force
  - High friction in draw die results in scoring

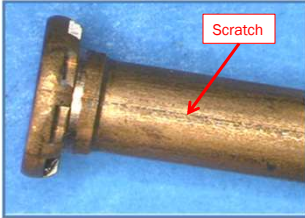
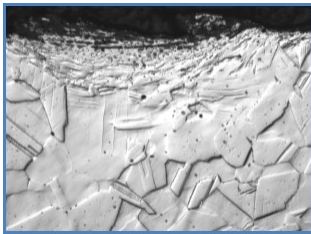
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 **Common Mill Problems- Scratches/Scoring**


- Appearance
  - May appear, by eye, like a seam
  - In cross-section: will have compressed grains
  - Depth is superficial


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 **Common Mill Problems- Pits/Voids**

- Pits/Voids are non-conformities that may be related to hot mill, cold drawing, or storage/handling
- Causes
  - Contact with any object that results in a pit or void
  - Absence of material in a localized area
  - Pitting corrosion
- Appearance
  - Small divot or void
  - With pitting corrosion, pits may be clumped together



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 **Common Mill Problems- Underfill**

- Underfill is a non-conformities that may be related to hot mill or cold drawing
- Causes
  - Lack of material to provide the wire or bar with its true shape
- Appearance
  - Localized area of wire or bar that is out-of-shape, lacking material, or out-of-dimension



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 **Common Mill Problems- Hot Tear**


- Hot Tears are non-conformities related to the hot mill
- Causes
  - Hindered contraction during solidification or cooling after hot working
- Appearance
  - Fracture on the surface of the rod
  - Also known as a fisheye, burst, flake, shatter crack, snowflake crack or hairline crack




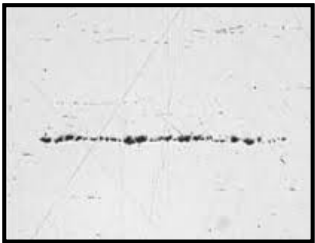
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 **Common Mill Problems- Non-Metallic Inclusions**


- What is a Non-metallic inclusion?
  - Chemical compounds and non-metals in steels and alloys
  - Product of chemical reactions
  - Contamination
  - Occur during melting and casting processes
- Indigenous Inclusions
  - Occur in the metal
  - Result of chemical reactions
    - Alloying elements
    - Precipitating gases
    - Residual elements from recycled scrap
- Exogenous Inclusions
  - External to the metal
  - Entrapment from
    - Slag
    - Flux residues
    - Mold linings

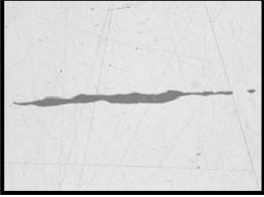
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 **Common Mill Problems- Non-metallic Inclusions**

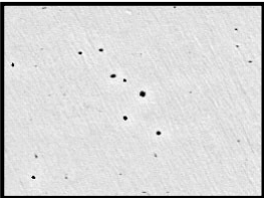
- Types of Non-metallic Inclusions
  - Sulfides- (Compounds containing S)
  - Oxysulfides- (Compounds containing S & O)
  - Nitrides- (Compounds containing Ni)
  - Silicates- (Compounds containing Si & O)
  - Oxides- (Compounds containing O)
  - Phosphides- (Compounds containing P)
  - Carbides- (Compounds containing C)
- Majority of inclusions are oxides and sulfides
- Silicates can be very detrimental to steels



Sulfide Inclusion



Silicate Inclusion




Globular Oxide Inclusion

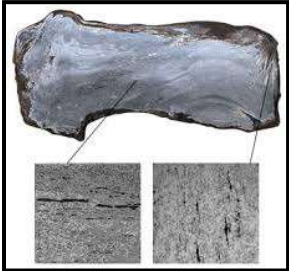
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 **Common Mill Problems- Non-metallic Inclusions**

- **Non-metallic Inclusions impact:**
  - Toughness
  - Ductility (Cause cracking)
  - Fatigue Strength
  - Corrosion Resistance
  - Tensile Strength
- **Steel making process:**
  - Steel generally contains 0.01-0.02%
  - Fewer inclusions= “cleaner” or “better quality” steel
  - Inert Gas stirring in Ladle Furnace
  - Vacuum Ladle Degassing



RMS Titanic Rivets with Inclusions

Source: www.civildatas.com

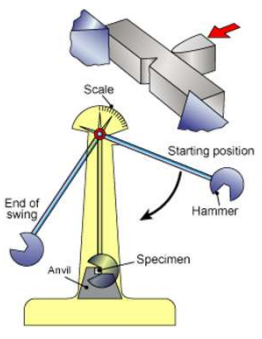
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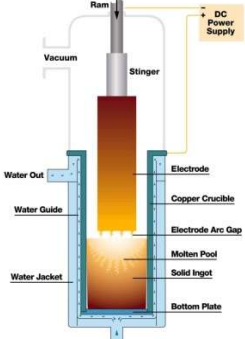
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**Common Mill Problems- Non-metallic Inclusions**

- **Prevention and Discovery:**
  - Inert Gas stirring in Ladle Furnace
  - Vacuum Ladle Degassing
  - Vacuum Induction Melting
  - Electro Slag Remelting
  - Vacuum Arc Remelting
  - Cross section/micrographs
  - Charpy Impact Test



Charpy Impact Tester



VAR


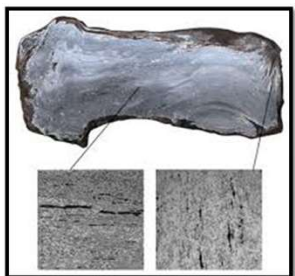
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**Common Mill Problems- Non-metallic Inclusions- Contributors in Fastener Failures**

- From NIST Report NIST-IR6118 by Tim Foecke and titled "*Metallurgy of the RMS Titanic*":
  - "It has been found that the wrought iron rivets used in the construction of *Titanic* contained an elevated amount of incorporated slag, and that the orientation of the slag within the rivets may hold an explanation for how the ship accumulated damage during its encounter with the iceberg."
  - "The microstructure of the rivets is the most likely candidate for becoming a quantifiable metallurgical factor in the loss of *Titanic*."

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## Common Mill Problems- Non-metallic Inclusions- Contributors in Fastener Failures

- From *Report on the A354 Grade BD High Strength Steel Rods on the New East Span of the San Francisco-Oakland Bay Bridge, With Findings and Decisions* dated July 8, 2013:
  - “There was evidence of elongated inclusions (i.e. the presence of particles in a long and thin pattern) laying in the same direction as the ferrite, pearlite and transformed martensite banding;”



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## Common Mill Problems- Decarburization

- What is Decarburization?
  - Loss of carbon at the surface of steel. It is caused by exposure of the surface to oxidizing conditions at high temperature
- Where in the Mill Process can this occur?
  - Billet/Ingot normalizing
  - Hot rolling
  - Annealing



Courtesy: Tri Star Metals

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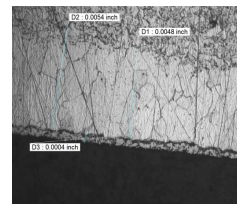
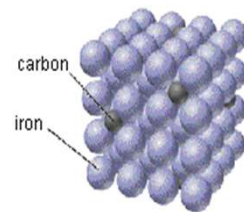
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## Common Mill Problems- Decarburization

- Mechanism:
  - Carbon atoms are relatively small compared to iron atoms.
  - At higher temperatures, carbon can move quite readily between iron atoms.
  - Carbon near the surface will react with oxygen forming CO/CO<sub>2</sub>.
  - Carbon will diffuse toward lower concentration zones – like water running downhill.
- Causes:
  - No protective atmosphere
  - Incorrect protective atmosphere settings
  - Leak in furnace
- Impact:
  - Decarburization can run deep – as much as 0.020" to 0.030".
  - Decarburized layers will not achieve the desired strength during heat treatment.



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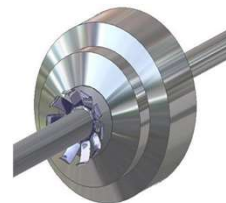
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## Common Mill Problems- Decarburization

- Prevention and Repair:
  - Furnace atmospheres controlled to prevent the oxidation of carbon at the surface of the metal
    - Gas generator to control the ratio of CO:CO<sub>2</sub> or carbon potential in the furnace
    - Inert or reducing atmosphere
  - Furnace maintenance
  - Shaving of wire
  - Process can be reversed for repair



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 **Common Mill Problems-Insufficient Coating**


- Purpose of Coatings
  - Prevents galling of wire in tooling by preventing metal-on-metal or metal-on-carbide contact
- Types of Coatings
  - Phos and lime
  - Phos and lube
  - Phos and polymer
  - Bare/Plain
  - Precoat
  - Molybdenum disulfide (Moly)
  - Soap
  - Lime
  - Wax
  - Polymer
  - Copper





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 **Common Mill Problems-Insufficient Coating**

- Stainless steels are especially sensitive to galling – robust coatings are necessary to cold head stainless.
- Coating needed is dependent on the process.
  - Degree of extrusion.
  - Number of stations.
- Impact:
  - Parts gall in tool
  - Tools break down quickly

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## Common Washer Problems

- Washers are used for SEMS (Assembled Washer Assemblies)
  - Fed onto a blank
  - Thread is rolled retaining them
  - Subject to all rolling problems (Discussed in Part 5)



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## Common Washer Problems

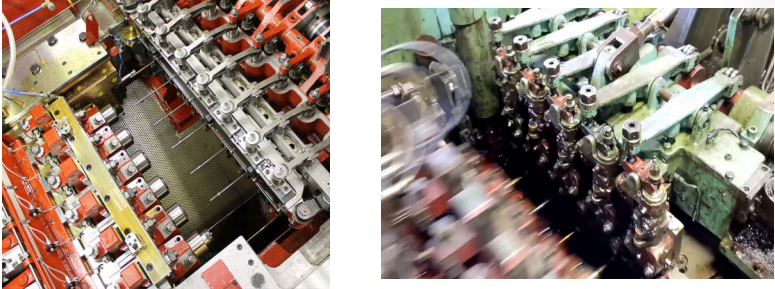
- Common Problems
  - Bent
  - Wrong ID
  - Mixed Material
  - Stuck Together
  - Brittle



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## Part 2: Problems in Forming

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## Forming Problems- Shear Bursts

- Shear Bursts: An open break in the metal located at approximately 45° angle to the product axis resulting from the material not having the capability to withstand the stresses or strain exerted upon it.

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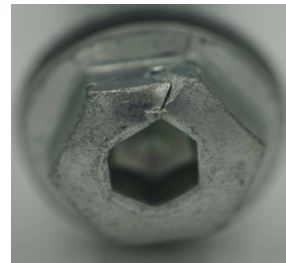
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## Forming Problems- Shear Bursts

- Common Traits:
  - Most frequently occur at periphery of products having flanges or circular heads
  - Are known to occur on the sides of hex head products
  - May be open or closed but will exhibit a characteristic 45° angled fracture surface



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## Forming Problems-Shear Bursts


- Causes:
  - Poor tool design or poor first blow upset
  - Overworking the material prior to upsetting.
  - Poor ductility due to coarse grain size (usually will see orange peel surface).
  - Insufficient lubrication
  - Rough surface on wire.
  - Cold drawing through die with steep approach angle.
    - The steeper the approach angle of the draw die, the more concentrated the cold work is on the surface of the wire.




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## Forming Problems-Shear Bursts



- Prevention/Solutions:
  - Usually this is a tool design/upset issue- reworking the geometry of the upset to move less material or redistribute material differently will solve the problem
  - Reduce the reduction % of the draw prior to heading
  - Check the wire for hard spots or other obvious surface flaws. Replace the wire.
  - Increase or redirect lubrication
  - Check the draw die to make sure that the approach angle isn't too steep. Re-polish and/or clean the draw die if there is any evidence that it is scoring the wire.

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## Forming Problems- Cracks and Bursts

- Cracks and Bursts: An open break in the metal, usually aligned with the part axis, resulting from a flaw or surface discontinuity opening up during forming.




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## Forming Problems- Cracks and Bursts

- Common Traits:
  - Most frequently occur at periphery of head along the axis of the part
  - May be closed or open
  - Are usually the result of a seam, lap, scratch or other type of surface defect or discontinuity
  - Are easily evident when the result of a wire seam or lap.



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## Forming Problems- Cracks and Bursts


- Causes:
  - Wire seams
  - Wire laps
  - Scratches/scoring
  - Worn out upset
  - Inclusions near the surface
  - Head Markings
  - Any flaw, defect, or surface discontinuity that results in localized stress concentration




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## Forming Problems- Cracks and Bursts




- Prevention/Solutions:
  - Use Seam and Decarb Free Wire
  - Replace the wire
  - Replace upset
  - Check the draw die and re-polish or replace if it is scratching/scoring the wire

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## Forming Problems- Forging Cracks

- Forging Cracks: Small cracks that usually appear at the surface, on the top of the head, sidewall, or at a sharp corner due to the pressure exerted during the forming/upsetting process.
- Forging cracks are often unsightly but if not larger or deeper than the specified allowances in Surface Discontinuity documents, they normally do not affect the mechanical performance or functionality requirements.



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## Forming Problems- Folds and Slivers

- Folds: A lapping, folding over, or doubling of metal that occurs during the forming process as a result of mismatched features or localized buckling. Folds normally occur at the intersection of feature/diameter changes around the head, shoulder, or shank of bolts and the intersection of feature changes/diameters on the top or bottom faces of nuts.



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## Forming Problems- Folds and Slivers

- Common Traits:
  - May be difficult to discern without etching or before plating
  - Common on hex washer parts
  - Folds may occur inside of recesses
  - Slivers form on the top heads that have a flat bearing surface and recess



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 **Forming Problems- Folds and Slivers**

- Causes:
  - Misalignment between blows
  - Slivers result from small amount of flash forming around upset pin that is pushed back down onto the surface



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 **Forming Problems- Folds and Slivers**

- Prevention/Solutions:
  - These problems are a result of set-up issues or sloppy tooling. Replacing tools or repairing the set-up should address these issue.



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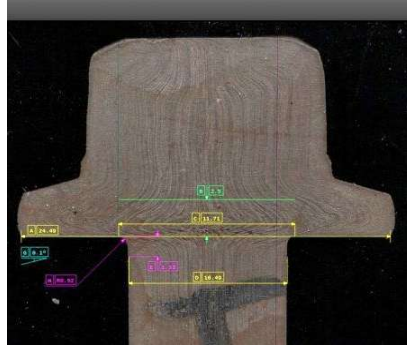
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## Forming Problems - Grain Flow

- Grain Flow: Following hot rolling the metal grains are distributed in long, continuous lines, much like long grain in a block of wood. When parts are upset, the material is redistributed and these longitudinal grain lines bend around and follow the shape of the newly formed upset feature.



Example of Grain Flow Specimen

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## Forming Problems- Grain Flow

- Common Traits:
  - Parts must have grain lines which smoothly and continuously bend around the change in shape
  - Parts that exhibit grain lines that are kinked (like a garden hose when it unravels) are unacceptable
  - Parts that exhibit grain lines that terminate in the fillet radius or into the shank are unacceptable
  - Parts with bad grain line patterns are vulnerable to breaking at loads significantly lower than anticipated.
  - Any part might be subject to grain flow check, but especially hex flange and hex washer head parts



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## Forming Problems- Grain Flow

SAEUSCAR-8 REVISION 2  
GRAIN FLOW PATTERN FOR BOLTS, SCREWS, AND STUDS  
Revised 2007-03  
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SAEUSCAR-8 REVISION 2  
GRAIN FLOW PATTERN FOR BOLTS, SCREWS, AND STUDS  
Revised 2007-03  
- 5 -

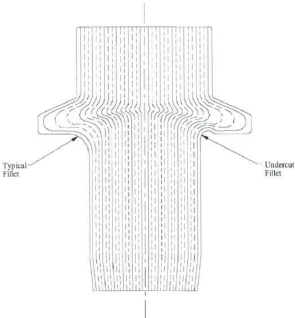


FIGURE 1 - Acceptable Grain Flow Pattern

GOOD

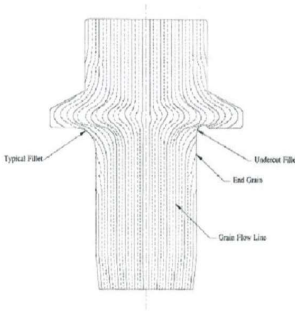



FIGURE 3 - Unacceptable Grain Flow Pattern

BAD

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## Forming Problems- Grain Flow

- Causes:
  - Good= Good Set-up
  - Bad=Bad Set-up
    - Length in upset is too short
    - Overall length is too great
    - Cut-off is not straight
    - Cut-off burr
    - Wire is oversized
    - Upset is not designed right
    - Bearing surface (die) is too smooth
    - Flange surface (punch) is too rough



Good

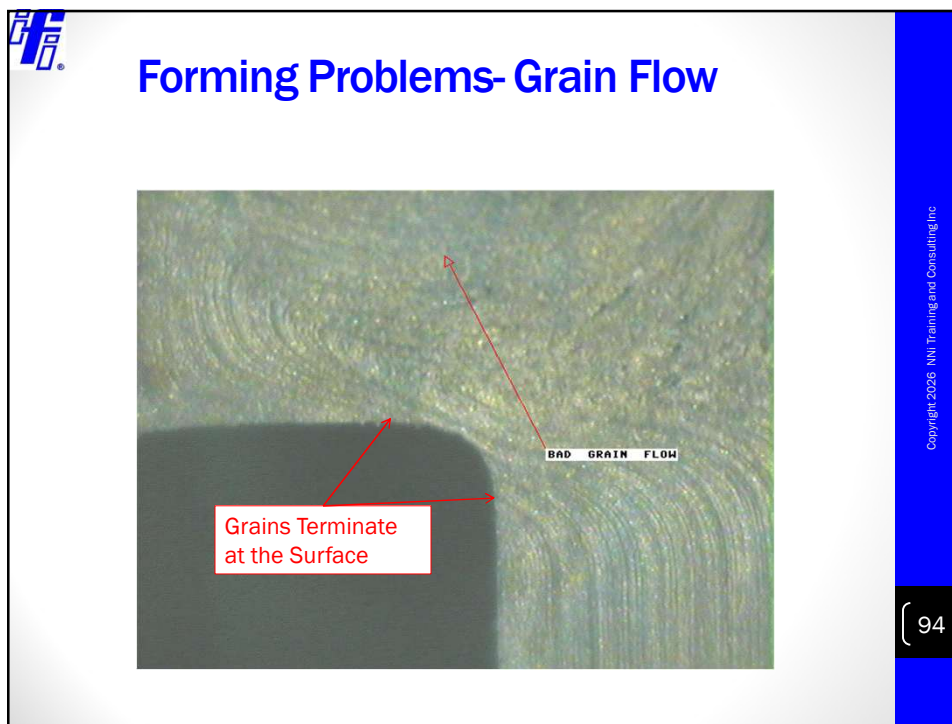


Bad

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## Forming Problems- Grain Flow

- Prevention/Solutions:
  - Conduct a grain flow check- involves sectioning the head, polishing, and etching in warm acid
  - These problems are a result of set-up issues or tooling issues. If a grain flow problem is discovered during the grain flow check, the tooling and set-up should be reworked until the grain flow check exhibits good grain flow.

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## Forming Problems – Adiabatic Shear Banding

- Adiabatic Shear Banding: An internal crack formed by a complicated metallurgical phenomenon that occurs when a part is exposed to high strains and high strain rates (characteristic of the cold heading process). In essence an adiabatic shear band is a narrow, planer band of large-scale shearing that occurs in metals that experience intense dynamic loading. Once the band is formed, the result is two separate and disconnected regions of material. Although the part will appear to have continuity on the outside it possesses an internal band characterized by separate or dislocated structures relative to one another. Perhaps more simply, a part with an ASB will appear normal on the outside but have an internal crack separating the formed feature (head or collar) into two parts.



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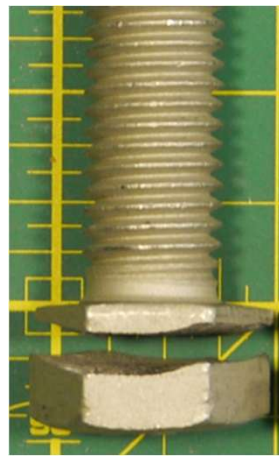
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## Forming Problems-Adiabatic Shear Banding

- Common Traits:
  - On the outside the part will, likely, appear normal
  - Once placed in a tensile test or loaded during tightening the band will fail – resulting in two pieces of the formed head
  - This condition occurs under extreme dynamic loading- this means high strains and high strain rates
  - This condition might be expected to occur more often in parts with thin heads or collars and those that require significant radial upsetting to accommodate a trim operation



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 **Forming Problems- Adiabatic Shear Banding**



ASB exposed during trimming- Note head diameter to shank diameter ratio and thinness of head.

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 **Forming Problems- Adiabatic Shear Banding**




ASB exposed through failed tensile test


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## Forming Problems- Adiabatic Shear Banding



- Prevention/Solutions:
  - This is caused by extreme dynamic loading. Therefore, slowing the process down and more slowly moving materials (i.e. adding intermediate progressions) is likely to solve this problem.

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## Forming Problems- Underfill

- Underfill: An absence or lack of material exists resulting in an inability to fully fill out a part feature.



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## Forming Problems- Underfill

- Common Traits:
  - The part may look odd, with features less defined or lopsided.
  - The part may exhibit a crater or void
  - Underfilled hexes do not perform well, resulting in driving or disassembly problems
  - Underfilled parts are often dimensionally incorrect



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## Forming Problems- Underfill


- Causes:
  - Trapped oil and air
  - Short feed
  - Damage to wire
  - Out of round or dimensionally incorrect wire



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## Forming Problems- Underfill


- Prevention/Solutions:
  - Venting dies
  - Redesign tooling progression, for example, extrude or trim hex head instead of forming it
  - Investigate and adjust feed wheels to prevent wire from slipping
  - Replace damaged wire



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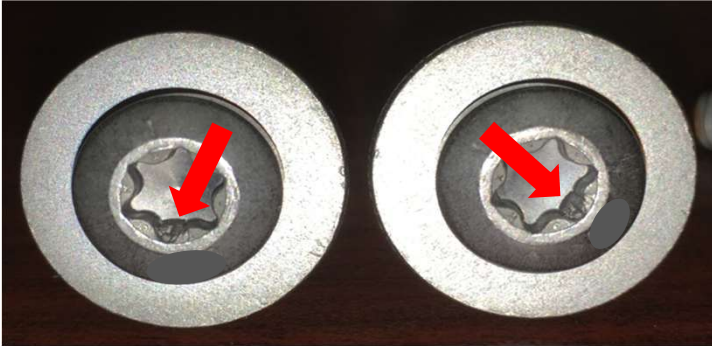
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## Forming Problems- Broken Punch

- Broken Punch: Either a partial or whole failure of a punch or punch pin resulting in a malformed part or recess.



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## Forming Problems- Broken Punch

- Common Traits:
  - Recess is obstructed and can't be used
  - Most often parts cannot be assembled, but if they can, reduced bit engagement results in premature camout
  - Hex or head punch can chip out leaving a deformed head



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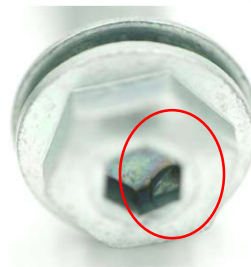
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## Forming Problems- Broken Punch


- Causes:
  - Punch wears Out
  - Metallurgy
  - Machine Timing (Transfer is moving before the punch is clear)
  - Part/Tool Alignment
  - Sloppiness in machine ram
  - Poor Lubrication




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## Forming Problems- Broken Punches




- Prevention/Solutions:
  - Properly set, in-process monitoring
  - Punch replacement program
  - Catch pan policy
  - Machine maintenance/overhaul
  - Improve set-up

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## Forming Problems- Scoring

- Scoring is the scratching of a part surface during extrusion
- Scoring is usually the result of
  - Polish wearing off the extruding land
  - Unequal loads being exerted in the extruding land
  - Breakdown or insufficient lubrication
- Scoring is caused by a galling mechanism between part and die, once a die starts to score a part, the die does not have long before irreversible damage occurs
- Prevention/solutions:
  - Re-polish the die
  - Improve lubrication
  - Replace the die



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## Forming Problems- “Baseball Caps”

- **Baseball Cap:** This is a manufacturing defect that occurs when control of the material is lost between the first upset blow and the finish blow. It is called a “baseball cap” because material squeezes out one side to give the appearance of the bill and dome of a baseball cap.



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## Forming Problems- “Baseball Caps”


- **Common Traits:**
  - Part resembles a baseball cap.
  - In extreme cases the baseball cap is combined with a shear burst and the head is almost unrecognizable.




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 **Forming Problems- “Baseball Caps”**


- Causes:
  - Wear in the upset- tool loses “control” of material flow
  - Broken upset spring
  - Sliding blow sticks and effectively becomes a solid blow
  - Off center 1<sup>st</sup> or 2<sup>nd</sup> blow
  - Misaligned transfer fingers or cut-off knife




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 **Forming Problems- “Baseball Caps”**

- Prevention/Solutions:
  - Use longer upsets to help reduce upset spring compression (anything greater than 30% compression decreases upset spring longevity)
  - Change Set-up
  - Periodically check for signs of tool wear



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## Forming Problems- Transfer Failures

- Problems related to transfer of parts
  - Part rotates from one station to the next
    - Result: Double hex or malformed feature
  - Transfer “clips” part leaving a nick or other external damage
    - Timing not set correctly
  - Broken punch
    - Transfer starts before the punch is clear of the part
  - Transfer drops part
    - Timed incorrectly
    - Top heavy
    - Worn finger



Groove for “Sticky Pin”

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## Forming Problems- Burr on Point


- Burr on Point
  - Characteristic of a point (such as a header point) that is driven in the forming operation
  - The knock-out pin is at the back of the die. It performs two functions:
    - It supports the part and prevents it from “shooting” out the other end of the die
    - It pushes the part out of the die during the exit stroke
  - There is a lot of pressure exerted on the point, so that a little material may “flash” around the pin.
  - If the pin “fit” is loose, some “flash” will form around the pin.



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## Forming Problems- Trim Burr

- Trim Burr
  - In trimming the part is pushed through a die that is the desired shape. The trimming process is just a shearing process. Often the manufacturer tries to pinch a little bit on both ends to prevent a burr from “wiping” off the end as the part is pushed through the die. As the tool dulls or if the material is especially soft, a burr can occur.




Note also the presence of forging cracks and a shear burst.

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## Forming Problems- Wire Coupling

- Connecting Wire Coils
  - Often manufacturers want to make more parts than one wire coil will make
  - If they have multiple coils from the same heat lot- they will connect them together
  - They may use either a welding method or a mechanical crimping method
  - The welding method is most common
    - Butt weld
    - Grind away over-weld
    - Paint the surface
    - Jog machine through its cycle when weld connection is near and remove the weld butt without forming it

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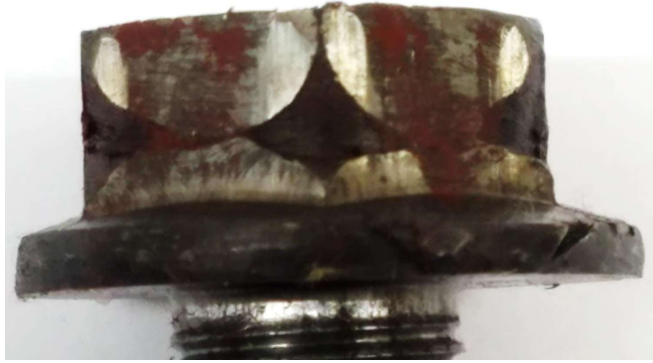
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## Forming Problems- Wire Coupling

- When the weld gets missed



We know this is from the weld because:

1. Red paint
2. Underfill from material removed in grinding
3. Shear bursts on flange represent "hard material" from weld zone

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## Forming Problems- Die Seam and Die Swell


- In hot forming large parts:
  - Die is split and opens up to accept part
  - Sometimes the pressure pushes a little material between this split and leaves a die seam mark
  - If this is extreme it may create a problem during assembly. Often these are removed by machining them off.
- The same thing can occur in cold forming
  - Using segmented dies
  - Conducting a secondary heading operation
- A similar issue can occur on some parts after they exit the die. There is a great deal of energy stored up as the parts are confined into a die. When the part exits, sometimes the part swells under the head leaving the first few thousands under the head larger in diameter.




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 **Forming Problems- Die Seam and Die Swell**



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 **Part 3:  
Thread Rolling and Tapping**



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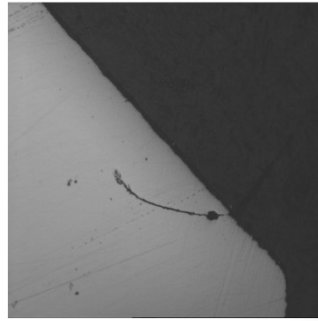
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## Rolling Problems- Thread Laps

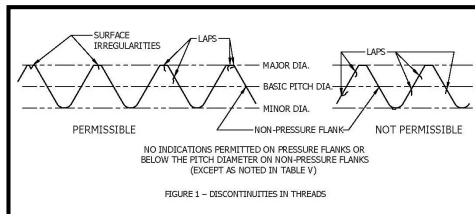
- Thread Lap: Doubling over of metal during the thread rolling process because of minor misalignment from one rotation to another



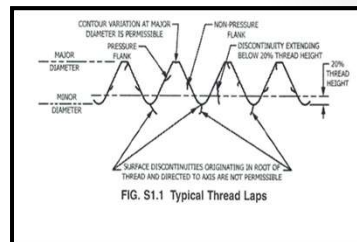
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## Rolling Problems- Thread Laps




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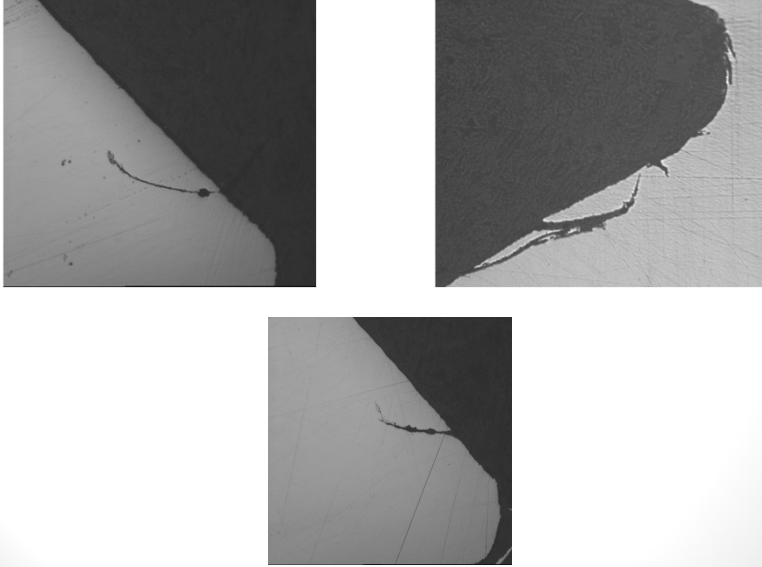


ASTM F788

- Common Traits:
  - Our general understanding is that thread laps are BAD
  - Thread laps are origination sites for fatigue cracks
  - Generally, the following are NOT permissible:
    - Below the pitch line (or ASTM 20% thread height)
    - Originating in the root and extending toward axis
    - Generally originating on either flank and extending toward axis
    - Originating anywhere on pressure flank and extending toward axis
  - Generally, the following are permissible:
    - Transverse to the axis and above the pitch line

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 **Rolling Problems- Thread Laps**



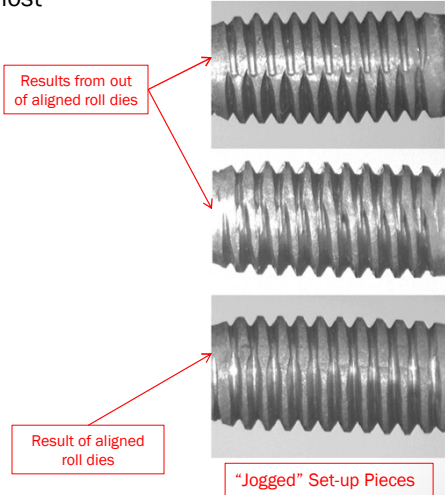
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 **Rolling Problems- Thread Laps**


- Causes:
  - Misalignment of dies (most prevalent cause)
  - Quality of blank
  - Improper die design
  - Tilting of blank
  - Slippage of blank
  - Die starting features
  - Condition of machine



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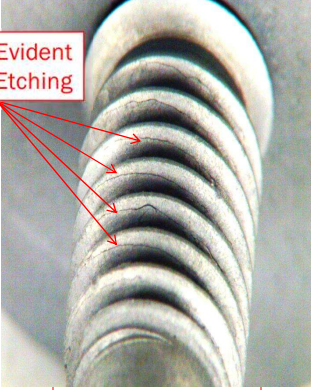
## Rolling Problems- Thread Laps

- Prevention/Solutions:
  - Oposing dies must be parallel to one another both top and bottom
  - Oposing dies must be matched- a check can be made by rolling a blank halfway in and out of a die and matching opposing thread starts
  - Confirm that pusher starts blank vertically and does not retract until the dies have hold of the part. Special considerations may be required for long or top heavy parts
  - Do not overfill threads- leave crests slightly under filled to compensate for die warm-up (excess material will roll into laps)
  - Do not over blast or manually nick thread start areas.

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## Rolling Problems- Thread Laps

Fume Hood-Acid Etch Station

Laps Evident After Etching


Etched Sample

Prevention: Check for laps during set-up using an acid etching station to expose laps.

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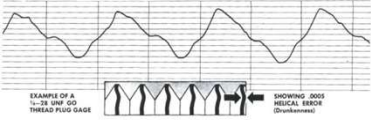

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## Rolling Problems- Drunken Thread

- Drunken Threads: Threads whose helix angles waver or are uneven

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## Rolling Problems- Drunken Threads


- Common Traits:
  - The thread has a crooked or wavering appearance
  - In very minor cases this condition might go unnoticed
  - In extreme conditions it is impossible to assemble such a part




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 **Rolling Problems- Drunken Threads**


- Causes:
  - Dies not in match
  - Tipped start
  - Crooked relief in dies
  - Slippage at start
  - Improper helix angle in dies
  - Inaccurate dies




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 **Rolling Problems- “Sliders”**

- “Sliders”: When a part fails to rotate and instead slides through the die



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## Rolling Problems- “Sliders”

- Common Traits:
  - The threads look completely mangled or stripped off the blank
  - Often sliders get drawn back into the die, bending the end and giving a hockey stick appearance



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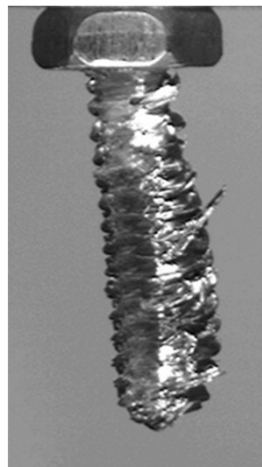
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## Rolling Problems- “Sliders”

- Causes:
  - Slippage at the start
  - Tipped start
  - Dies are not set-up right so that they are not applying adequate pressure
  - Too much lubricant



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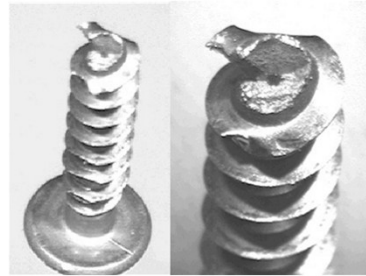
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## Rolling Problems- “Piping”

- “Piping”: A void or channel in the center of a screw caused by over rolling

When thread crests are overfilled (rolled sharp), little or no compensation is available for thermal expansion as the die heats up during prolonged runs or for blank diameter variation. The result is that the screw may end up barrel shaped because a void (or pipe) has formed in the center of the screw as material “flows” from the center to fill out the thread crests.



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## Rolling Problems- Piping

- Causes:
  - Pressure on the roll dies too high
  - Blank diameter error
  - Inadequate cooling
  - Inclusions in the raw material
  - Speed too high
  - Excessive wear of the tooling



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 **Rolling Problems- Missing Threads**


- Missing Threads: Parts that have some or all of their threads missing



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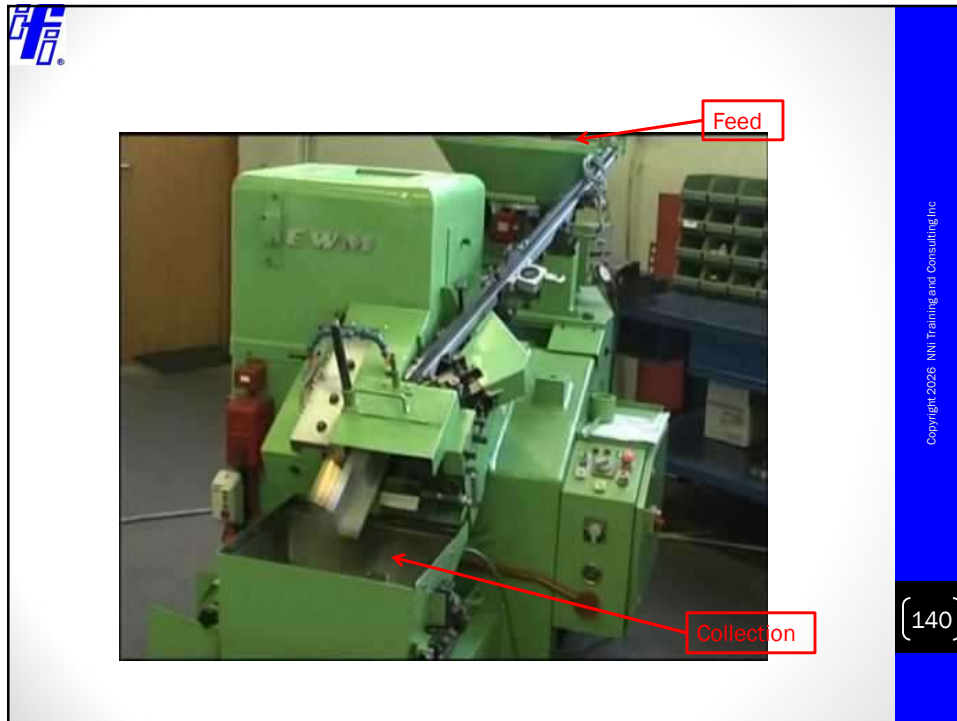
 **Rolling Problem-Missing Threads**

- Causes:
  - Exclusively a handling problem
  - Most commonly blanks are fed by gravity from an elevated position and exit machine from a location near the center or bottom of machine
  - During loading any parts that miss the feeder or become “over burden” during feeding and spill over, may bounce into the finished goods container

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## Rolling Problem-Missing Threads

- Prevention:
  - Position loading as far away from finish part collection site as possible
  - Make loading as low to machine as possible
  - Cover exit of machine
  - Cover collection area/containers of machine

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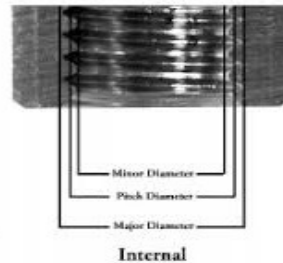
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## Tapping Problems- Insufficient Thread Percentage

- Thread Percentage: Refers to the percentage of the complete thread profile that can be formed during tapping. Although a 100 percent thread can be tapped, the torque required to do so can be multiple times larger than that necessary to form a 75 percent thread without a noticeable improvement in strength or performance of the thread.

Thread percentage is a function of the tap drill size. Regardless of whether the tap is a cutting or form tap, the tap drill will dictate how much material is present to provide the final thread. If the percent thread dips below about 60% the performance of the nut can be drastically reduced and the nut is at higher risk of stripping.



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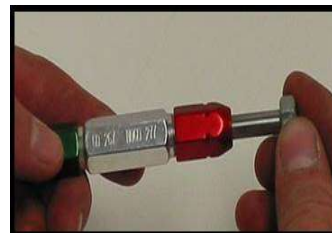
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## Tapping Problem-Insufficient Thread Percentage


- Prevention:
  - Use the right tap drill
  - Ream the hole if better precision is necessary
  - Be sure to gage the minor diameter using a Go/NOT GO pin



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## Tapping Problems- Slivers

- Slivers and chips that get trapped in in the threads

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## Part 4: Secondary Operations

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 **Problems with Machining/Shaving**

- Chatter- skipping of the tool, leaving characteristic “chatter” marks
- Tool Marks- wearing tool or wrong speed/feed
- Broken out tool
- Burrs
- Rings, chips, slivers


 Tool Marks

 Chatter Marks

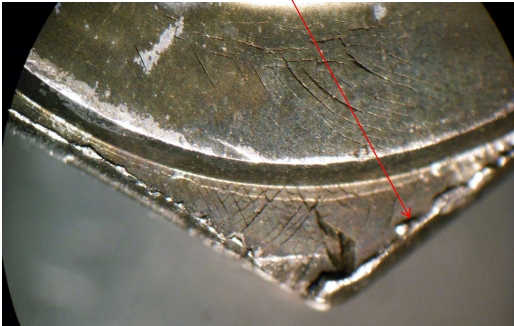
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 **Problems with Trimming**


- Burrs
- Deformation

 Trim Burrs


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 **Problems with Grinding**

- Burns
- Flat Spots



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 **Problems with Filet Rolling**



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## Problems with Fillet Rolling

- No deformation
- Too much deformation

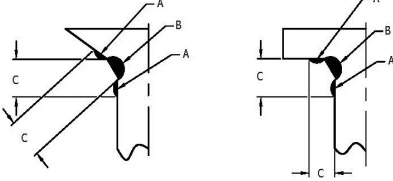


FIGURE 6 – FILLET COLD WORKING DISTORTION  
Note: Permissible distortion limits per TABLE VII.

TABLE VII – PERMISSIBLE FILLET DISTORTION LIMITS /a/ <sup>⑩</sup>

NOMINAL SIZE	Under .3125	.3125 to .3750	.4375 to .6250	.7500 to 1.0000	Over 1.0000
	C MAX	.062	.094	.125	.156
	REDUCED HEAD TYPE III ONLY				
	.031	.047	.062	.078	.094

Note: /a/ Cold working of head to shank fillet may cause distortion of the fillet area. Distortion shall not exceed .002 inch above (A) or below (B) contour shown on fastener drawing. Distorted area shall not extend beyond "C" as illustrated above.

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Questions?

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## Part 5: Handling

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## Problems with Handling

- Exit velocity nicks surfaces and threads
- Dropping parts from high levels nicks surfaces and threads




- Overflowing tubs can result in part damage or bend long, skinny parts

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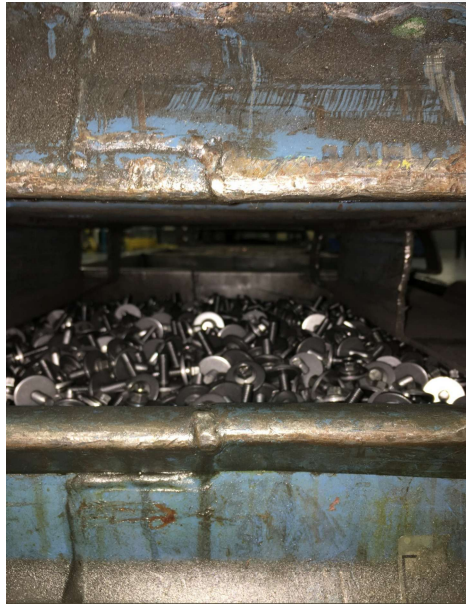
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## Handling

Filling tubs full and stacking one on top puts parts at risk to get caught and damaged in pinch points



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## Part 6: Heat Treating



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 **Heat Treating Problems- Missed Heat Treating**

- A part missing heat treatment altogether could be for several reasons, but is most likely, a material handling issue.


A Story of Missed Heat Treatment





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 **Heat Treating Problems- Missed Heat Treatment**

- Prevention/Solutions:
  - Vendor should have a policy to not collect parts in the same container they received them in
  - Vendor should have a policy in-place to double check that the container just emptied is truly empty of all parts



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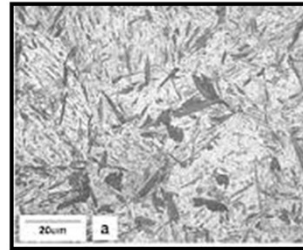
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## Heat Treating Problems- Untempered Martensite

- Untempered Martensite- Formed in a non-equilibrium process, Martensite is a solid solution structure of steel resulting from the rapid quenching from Austenite. The product of rapidly quenching Austenite (a FCC structure) is Untempered Martensite (a highly strained BCT structure). Although very strong, Untempered Martensite is very brittle. Tempering must be included to restore toughness..

**Because Untempered Martensite is very brittle, parts that have even small amounts of it present are prone to crack initiation or brittle failure**



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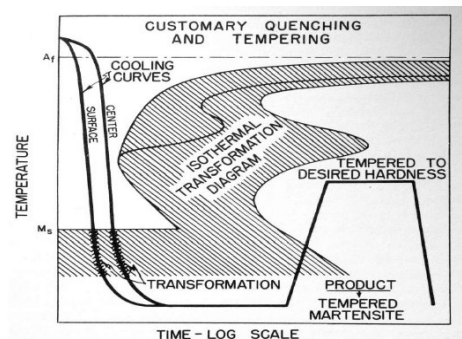
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## Heat Treating Problem-Untempered Martensite

- Causes:
  - Improper heat treatment
  - Exposure to localized high heating such as overheating during grinding or welding
  - Retained austenite transformation



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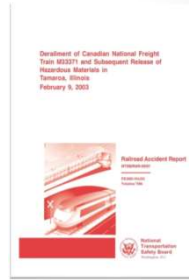
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## Heat Treating Problems- Untempered Martensite



Source: www.fhwa.dot.gov



Source: NTSB

- February 9, 2003 Derailment of Canadian National Freight Train M33371 in Tamaroa, Illinois
- Per NTSB PB2005-916301:
 

“Probable Cause: The National transportation Safety Board determines that the probable cause of the February 9, 2003 derailment of Canadian National train M33371 in Tamaroa, Illinois, was Canadian National’s placement of bond wire welds on the head of the rail just outside the joint bars, where **untempered martensite** associated with the welds led to fatigue and subsequent cracking that, because of increased stresses associated with known soft ballast conditions, rapidly progressed to rail failure.”

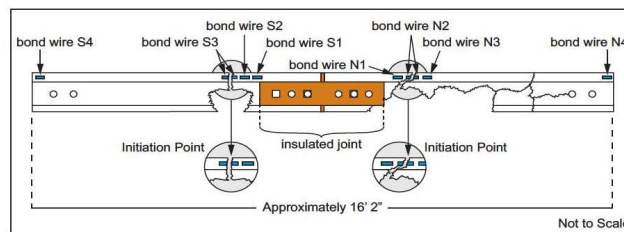
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## Heat Treating Problems-Untempered Martensite




**Figure 2.** Illustration of the insulated joint plug that failed at Tamaroa showing fracture locations. Three exothermic bond wire welds had been made at the head of the rail on either side of the insulated joint. (Letter designations indicate north or south portions of the plug.)

Source: NTSB Report

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 **Heat Treating Problems- Untempered Martensite- Retained Austenite**

- Retained Austenite: Austenite that did not fully transform to Martensite upon quenching


Causes:

- Steel that fails to be quenched past its  $M_f$  (Martensite Finish temperature)
- $M_f$  is normally below room temperature for alloys with greater than 0.3% C


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 **Heat Treating Problems- Untempered Martensite- Retained Austenite**

- Problem:
  - Austenite is the high temperature phase of steel
  - It is metastable at room temperature
  - It will transform to Martensite if given the opportunity to do so
  - This transformation can result in:
    - Increase in volume (throws off dimensional stability)
    - Internal stresses
    - Untempered Martensite
- Prevention:
  - Multiple Tempering
  - Cold treatment (cryogenic soak)



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## Heat Treating Problems- Quench Cracks

- Quench Crack: A condition that is usually limited to high carbon and high hardenability steels. The volume expansion resulting during quenching places residual stresses that exceed a parts Ultimate Strength and thus the part forms cracks to relieve this stress.



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## Heat Treating Problems- Quench Cracks

- Common Traits:
  - Usually limited to high carbon and high hardenability steels
    - 4140
    - 4340
    - 52100
  - Can occur very quickly after quenching
  - Large diameter parts or parts with large cross sections are more vulnerable



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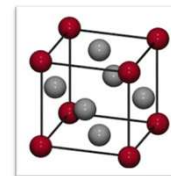
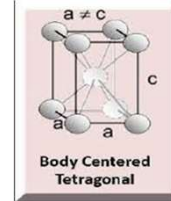
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## Heat Treating Problems- Quench Cracks

- Causes:
  - Volume expansion
    - Austenite is closely packed Face-centered-cubic
    - Martensite is Body-centered-tetragonal (~4% volume expansion from FCC)
    - Surface cools first and has volume expansion placing it in compression
    - Later center cools and has its volume expansion that is constrained by the outer layer of previously transformed martensite
    - This now places the surface in tension
    - If tensile residual stresses are greater than ultimate tensile strength of the surface a crack will form



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## Heat Treating Problems- Quench Cracks



- Prevention/Solutions:
  - Reduce or eliminate surface discontinuities (burrs, laps, rough surfaces)
  - Geometry changes
    - Increase transitional radii
    - Reduce extent of transitional differences between concentric cylinders
  - Slow down quench speed
  - Bring austenitizing and quenching temperature closer together
  - Institute a "Snap Temper"

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## Heat Treating Problems- Distortion

- Distortion: The bending or warping of parts



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## Heat Treating Problems- Distortion

- Causes:
  - Residual Stress
    - Can be from cold forming, coil memory, etc...
    - Areas in tension and in compression
    - Heat treatment relieves these stresses and can result in part distortion
    - Usually only a small portion of the overall distortion
  - Thermal Expansion and Contraction
    - At Austenitizing temperature parts expand
    - Ex. 10" long bar of 1045 will be 3/32" longer at 1600° F
    - As parts cool- cross sectional and core/surface differentials can result in stresses and distortion
    - For fasteners overall distortion from thermal expansion and contraction is relatively small

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## Heat Treating Problems- Distortion

- Causes:
  - Material Creep
    - 10 length to 1 diameter ratio places part at distortion risk
    - Creep- combination of high stress and high temperature result in part “growing”
    - When parts are loaded on one another, the weight of the parts on top press on the parts below, which at Austenitizing temperatures, can result in warpage
  - Metallurgical Transformation
    - During heat treatment, two transformations occur
      - On heating (Austenitizing)- material shrinks
      - On quenching- material expands
    - Gradients
      - Temperature differences between surface and core
      - Martensite percentage differences between surface and core
    - Resulting stresses can result in distortion

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## Heat Treating Problems- Distortion



- Prevention/Solutions:
  - Rack heat treat versus bulk methods
  - Reduce residual stress concentrators, i.e. maximize radii
  - Consider an alternate heat treating approach, such as Austempering or Marquenching

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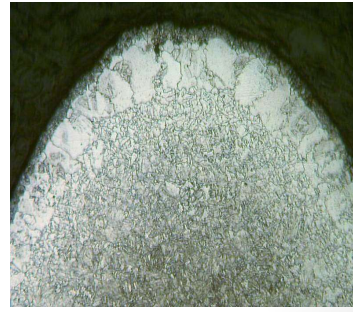
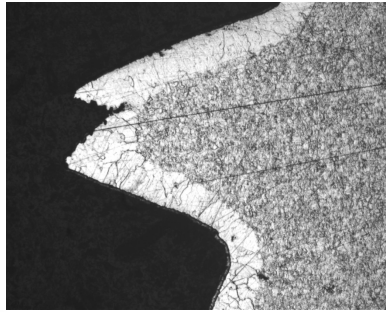
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## Heat Treating Problems- Decarburization

- Decarburization: Loss of carbon at the surface of steel. It is caused by exposure of the surface to oxidizing conditions at high temperature (Note: The reverse process, unintended carburization, may also pose a problem)



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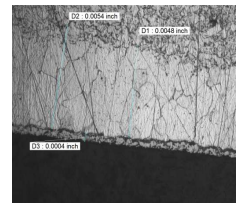
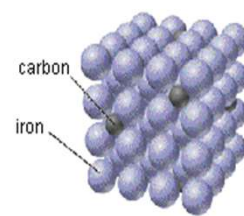
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## Heat Treat Problems- Decarburization


- Mechanism:
  - Carbon atoms are relatively small compared to iron atoms.
  - At higher temperatures, carbon can move quite readily between iron atoms.
  - Carbon near the surface will react with oxygen forming  $\text{CO}/\text{CO}_2$ .
  - Carbon will diffuse toward lower concentration zones – like water running downhill.



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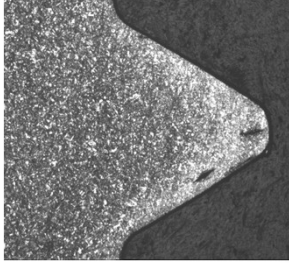
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## Heat Treat Problems- Decarburization


- Causes:
  - No protective atmosphere
  - Incorrect protective atmosphere settings
  - Leak in furnace
- Impact:
  - Decarburization can run deep – as much as 0.020” to 0.030”
  - Decarburized layers will not achieve the desired strength during heat treatment
  - Decarburization can occur in raw material or on finished parts. How do you distinguish where it occurred?



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## Heat Treating Problems- Decarburization


- Prevention/Solutions:
  - Furnace atmospheres controlled to prevent the oxidation of carbon at the surface of the metal
    - Gas generator to control the ratio of CO:CO<sub>2</sub> or carbon potential in the furnace
    - Inert or reducing atmosphere
  - Furnace maintenance
  - Shaving of wire
  - Process can be reversed for repair



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## Part 7: Plating and Coating

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## Plating and Coating Problems- Threads Don't Gage

- Problem: When verifying parts using System 21 inspection- the parts will not accept a GO threaded ring gage. They then become subject to rejection.
- Causes:
  - Too much plating or coating
  - Using the wrong ring gage
  - Nicks



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## Plating and Coating Problems- Threads Don't Gage




What happens if I try to  
add cream to this cup  
of coffee?

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## Plating and Coating Problems- Threads Don't Gage

### Dimensional Effects of Coating

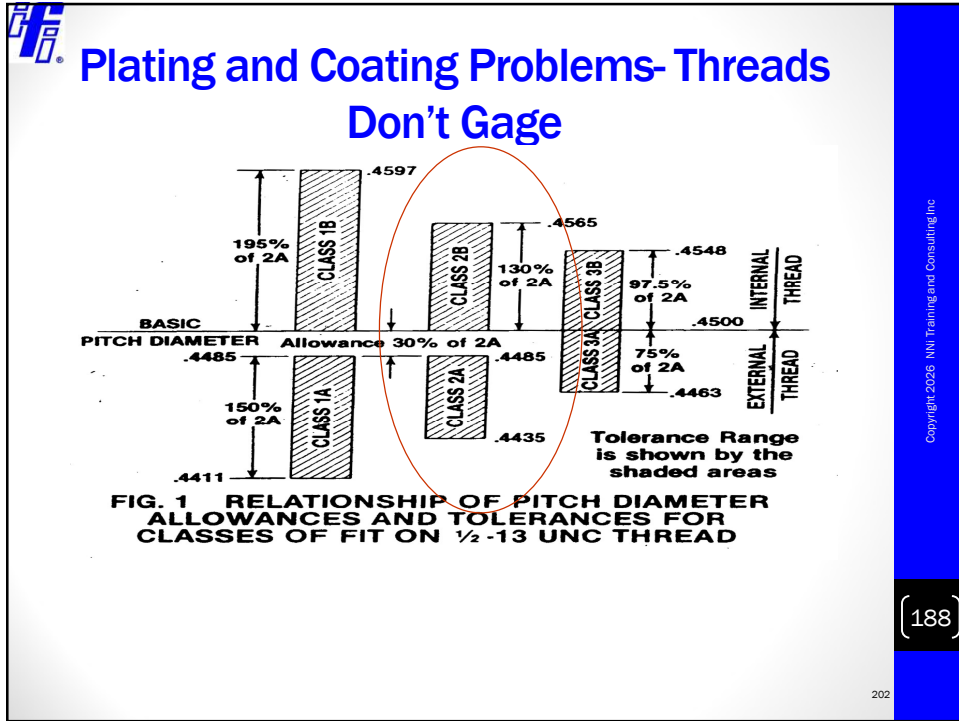
7.3.2 Because the coating thickness is measured perpendicular to the coated surface, while the pitch diameter is measured perpendicular to the thread axis, the effect of a uniformly coated thread flank on the pitch diameter is a change of **four times the thickness of coating on the flank.** (Note: Rule applies only to threads with a 60° thread profile.)

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## Plating and Coating Problems- Threads Don't Gage

**System 21.** Provides for *interchangeable* assembly with *functional size control* at the maximum material limits within the length of standard gaging elements, and also control of the characteristics identified as NOT GO functional diameters.

**Inspection Requirements:**

Thread Type:	Thread Characteristics	Most Common Gages
External	Functional (PD) Dia. Major Dia.	GO/NOGO Rings Micrometer
Internal	Functional (PD) Dia. Minor Dia.	GO/NOGO Thrd Plug GO/NOGO Pins

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## Plating and Coating Problems- Threads Don't Gage

- When plating makes the PD bigger, what does this mean for a system 21 (attribute style) gaging system?
  - Go Gage
- Rule 1: After Plating the part should **NOT** accept a 6g Not Go gage and should accept a 6h Go gage. **NOT A 6g Go Gage!**
- Rule 2: Unless the print says "6g After Plating" it is understood to be before plating only.



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## Plating and Coating Problems- Threads Don't Gage

Rule	Standard
Pitch diameter is changed by 4x the plating thickness	B1.1
External Thread Class 2A applies PRIOR to Coating	B1.1
After Coating gage acceptance is subject to Class 3A GO Ring Gage and Class 2A NOT GO	B1.1
On internal threads, the threaded GO Plug Gage must pass through the full-threaded length of the product freely	B1.2
On internal threads, the threaded NOT GO Plug Gage must not enter more than three complete turns	B1.2
On internal threads, the GO Cylindrical (unthreaded) Plug Gage must pass through the length of the product without force. The NOT GO Cylindrical Plug Gage must NOT enter.	B1.2
On external threads, the thread must freely enter the GO Threaded Ring Gage for the entire threaded length.	B1.2
On external threads, the thread may NOT enter the NOT GO Threaded Ring Gage more than three complete turns	B1.2
A product is considered acceptable when it passes a test by ANY one of the permissible gages in ASME B1.3	B1.2
Provisions have been made for parts that have thread nicks and will not freely enter a GO Threaded Ring Gage	ASTM F788


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 **Plating and Coating Problems- Threads**  
**Don't Gage**


- Prevention/Solutions:
  - Investigate alternate finishes and/or processes that result in less plating build-up
  - Make sure that the right gage is being used- verify that your customer is using the right gage
  - Review the design and adjust for a larger allowance with thicker platings
  - Utilize the standards for nick compensation



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 **Plating and Coating Problems- Fill**

• Fill: This is a problem that occurs especially with dip spin finishes, where the high viscosity of the plating results in fill to recesses, crevices, and threads


- Causes:
  - Generally, the dip spin process is not capable of evacuating excess coating from small recesses 100% of the time.
  - Process parameters are off
  - Coating is too viscous




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 **Plating and Coating Problems- Fill**



- Prevention/Solutions:
  - Consider alternative finishes for parts 6mm or under with an internal recess
  - Consider converting internal drive systems to external drive systems
  - Consider using a recess that has features to aid in the evacuation of excess coating materials
  - Consider using a different spinning process that is more capable of evacuating excess coating

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 **Plating and Coating Problems- Debris**

- Debris: This is a problem where foreign debris gets lodged in the threads or recess.

- Causes:
  - Artifacts from mechanical cleaning (such as glass beads trapped in threads or recess)
  - Foreign material gets picked up from contaminated process line (such as a roll-off point tip from another part that was intermixed with parts, fell out during plating, and contaminated the plating operation.)
  - Contaminated containers
  - Parts spilled during handling




This part got stuck in a Wheelabrator during mechanical cleaning. In addition to the debris, the threads have been badly damaged from constant contact with other parts.


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 **Plating and Coating Problems- Debris**


- Prevention/Solutions:
  - See that vendors line tubs with paper (or equivalent) to prevent contact with contaminated surfaces.
  - Audit vendor's maintenance practices on their tanks and equipment- how often are they "cleaned" to remove any foreign debris
  - Handle parts that have cut-offs carefully- make efforts to separate chips, shavings, and cutoffs from parts before processing them
  - If parts are mechanically cleaned, be sure that bead size is small enough to not get trapped in part recesses or threads



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 **Plating and Coating Problems- Burnt Plating**

- Burnt Plating: Part exhibits scorch or arc marks

- Causes:
  - In electroplating if a barrel should stop rotating, be too full, or otherwise cause parts to come in contact with the barrel electrode, it is possible that an arc or burn mark can be left on a part.





Disclosure: Please be aware that this part is NOT electroplated, and therefore, would not have been exposed to an electrode. It is shown here, however, as an example because the appearance is similar to what might occur on an electroplated part.

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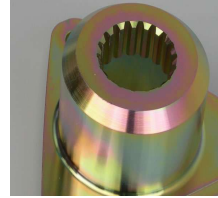
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## Plating and Coating Problems- Blotchy Finish/Iridescence

- Iridescence: Part exhibits iridescent or rainbow-like patches
- Causes:
  - Electroplated parts can exhibit a wide range of color shades and variations. There is a complicated set of reasons for this, but on a simple level, it represents the expected variation in a process that has many moving parts (variables). Normally, different color shades, blotchy patches, and iridescence may be distracting or bothersome to the customer, but do not degrade the performance. However, if the customer has established appearance criteria, these problems may result in parts not being acceptable.



Note iridescence

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## Plating and Coating Problems- Salt Spray Testing

- Problem: Salt Spray testing is commonly used as a qualifier for the expected performance of platings and coatings, however, test results are often widely variable and do not agree from one test chamber to another.
- History:
  - First salt spray testing was in 1910
  - First release of ASTM B117 was in 1930's
  - Early versions called for 20% salt
    - Clogged up fogging apparatus
  - B117 was revised in 1954 to current day 5% salt
  - Average marine environment is 1.8%-3%



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## Plating and Coating Problems- Salt Spray Testing

- Pros
  - Test is accelerated
  - Good process control tool
  - Easy to perform
  - Most widely used and accepted
- Cons
  - No known correlation to real life behavior
  - No consistency or correlation of test results between two properly functioning cabinets
  - Likely to fail parts that have passed in another cabinet
  - Not a good qualitative test


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## Plating and Coating Problems- Salt Spray Testing



- Prevention/Solutions:
  - Educate yourself and your customers on what the standards have to say- use ASTM B117 to illustrate limitations of cabinet to cabinet results
  - Do not bake parts after chromating and sealing
  - Do not use test samples that have been through sorting, packaging, shipping, or any other process that exposes them to part-on-part contact
  - Use the test only for in-process control purposes

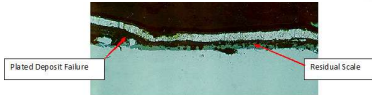

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## Plating and Coating Problems- Adhesion

- Problem: The plating or coating does not want to adhere to the part.
- Poor adhesion is usually a sign that the part was not sufficiently prepared for the plating or coating
- High strength, heat treated fasteners can pose a significant challenge to prepare
  - Over aggressive preparation by acid pickling can result in a carbon-rich surface that hinders adhesion. It may also generate more hydrogen creating a increased hydrogen embrittlement risk
  - Under preparation results in residual scale being left behind which may also hinder adhesion

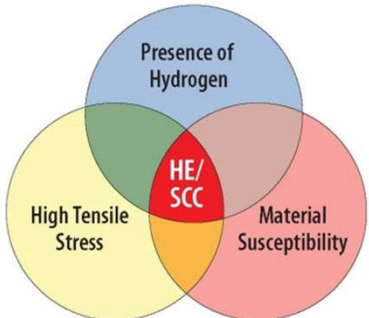
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## Plating and Coating Problems- Hydrogen Embrittlement

- Problem: Both the electrocleaning and electroplating components of a electroplating process expose fasteners to atomic hydrogen. The exposure to atomic hydrogen in parts that exhibit material susceptibility place the fasteners at risk of hydrogen embrittlement.




- For Hydrogen Embrittlement to occur:
  - It requires a nexus of these three factors
  - It requires time

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 **Plating and Coating Problems- Hydrogen Embrittlement**


- **What is it?**
  - Big Misconception- Normally considered a **Root Cause** when, in fact, it is a mechanism of failure
  - Defined- it is a permanent loss of ductility in a metal or alloy caused by hydrogen in combination with stress, either externally applied or internal residual stress. (ASTM F2078 *Standard Terminology Related to Hydrogen Embrittlement Testing*)
  - Internal Hydrogen Embrittlement (IHE)
    - Source of hydrogen is from steelmaking, plating, or cleaning processes
  - External Hydrogen Embrittlement (EHE)
    - Sources of hydrogen are from environmental exposure when the fastener is under stress
    - Stress Corrosion Cracking (SCC)
    - Hydrogen Induced Stress Corrosion Cracking (HSCC)
    - Cathodic Hydrogen Absorption (CHA)
      - Results during corrosion process

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 **Plating and Coating Problems- Hydrogen Embrittlement**





- **Prevention/Solutions:**
  - Limit hardness to HRC39 or less
  - Be very cautious about processing parts above Property Class 10.9 (Grade 8)
  - Limit coatings and finishes to low risk processes (free from significant hydrogen sources)
  - Use acid inhibitors during acid pickling
  - Bake parts according to relevant standards or longer
  - If electroplating zinc- consider a non-electroplated equivalent or perhaps a zinc-nickel alternative

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## Part 8: Methods of Detecting Problems

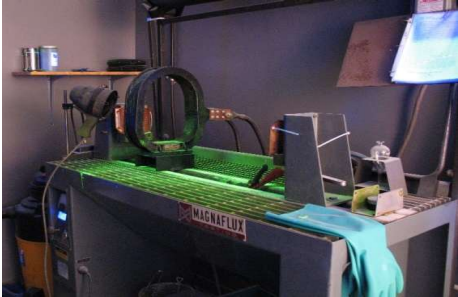

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## Non-Destructive Testing (NDT)

- Used to discover flaws or potential flaws that cannot be seen by the eye- particularly looking for cracks, laps, and other surface discontinuities
- For Ferrous Parts (Steel)- **Magnetic Particle Process**
- For Non-Ferrous Parts (Stainless Steel, Titanium, Al, etc...)- **Dye Penetrant Process**

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## Sorting- General Comments

- In certain segments of the fastener industry sorting has become second nature
- Sorting, however, is not a value added activity
- No sorting process is absolutely perfect
- Targets and goals for sorting should be reviewed internally or with supplier to assure that best method available for sorting is chosen
- Not all sorting methods are equally good
- Most automotive companies require a containment or safe launch period at the outset of shipping parts



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## Sorting- Manual


- In most cases is the least accurate of all sorting types- may only be 80-85% effective.
- There are sorts, however, that can only be done manually, such as special gauge sorts.
- Manual sorts are good for:
  - When parts must go through a special gauging process that is not easy or practical to replicate on an automated piece of equipment
  - Timing/implementation is critical- a manual sort can usually be started immediately
  - Target is to cull out parts with subjective criteria- such as shade of color or part appearance
  - Other hard to detect items by automated equipment- such as punch break-out in a recess
- Disadvantages of manual Sorting:
  - Time
  - Throughput
  - Accuracy
  - Cost



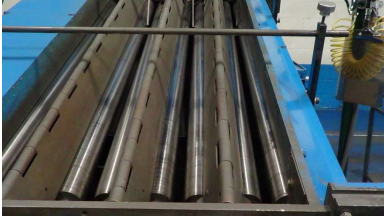
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 **Sorting- Automated Mechanical**

- Roller Sort
- Bowl Sort
- When to employ this method:
  - Sorting for simple criteria such as foreign material or head diameter
  - Throughput is needed
  - Cost is a concern
- Disadvantages:
  - Limited capability



Example Roller Sorter




Example Bowl Sorter

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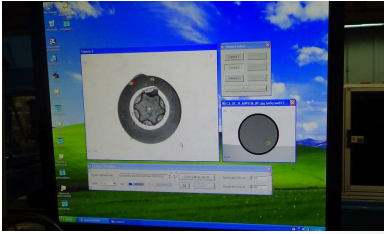
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 **Sorting- Vision Systems**

- Shadow Projection
- Camera
- When to employ this method:
  - More complicated sorting criteria- dimensional features of heads, recess fill, cracked heads, presence of features
  - Throughput is needed
- Disadvantages:
  - Limited to ability for the camera or shadow to "see" desired item
  - Slower and less cost effective than some other methods
  - Requires careful set-up and process control



Camera Sorter



Camera Sorter

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## Sorting- Innovations and Advancement

- Camera Technology has come a long way
  - High-Definition Cameras
  - Linear Cameras
  - Balancing the light source and camera
- Crack Detection
  - Combination of Eddy Current Technology and High-Definition camera images
- Glass Tables
  - Allow sight pictures from above, below, or to the side
- AI
  - AI can be a powerful tool to improve the capability and reliability of identifying patterns and defects

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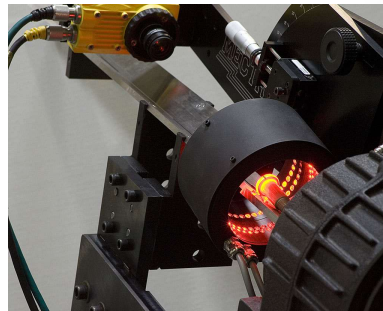
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## Sorting- Laser Systems

- When to employ this method:
  - High dimensional criteria is desired
- Disadvantages:
  - Ability is limited by number of lasers
  - Limited to what the laser can "see"
  - May be slower and less cost effective than some other methods
  - Requires careful set-up and process control



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## Sorting- Eddy Current

- When to employ this method:
  - When determining unseen internal hardness is necessary
  - Good for discriminating significant hardness differences, material differences, and volume differences
- Disadvantages:
  - Capability is limited to discriminating features described above
  - Slower and less cost effective than some other methods
  - Requires careful set-up and process control



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## Part 9- When a Quality Spill Occurs

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**What do you do when posed with a quality spill?**



Panic ?

Dive right in and try to solve it?



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**What do you do when posed with a quality spill?**



Collect information and work the problem in an organized and systematic fashion?

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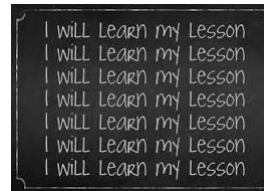


## A Quality Spill

Louis Pasteur once said, "Chance favors only the prepared mind."

Things to consider BEFORE a quality spill occurs:

- You WILL occasionally experience quality spills
  - Odds favor that eventually one or more will have the chance of significantly, negatively affecting your bottom line
  - Do NOT discount that every quality spill has the potential of ruining your company
- Be prepared
  - Run a "drill"
  - Generate a procedure
  - Keep a log of lessons learned



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## A Quality Spill

- Dynamics
  - Emotions can run high
  - Costs and demands, sometimes seemingly irrational, can accumulate quickly
  - Everyone starts pointing fingers
  - "Sides" form and "prepare" for battle
  - All of this is counter-productive and ends in a no-win situation for all involved parties
- What to do instead
  - Act professionally
  - Find parties on both sides that can act as "the voice of reason"
  - Follow your plan/protocol
  - Continue to remind all parties that the ultimate goal is to FIND THE ROOT CAUSE and eliminate it
- In every situation where the supplier and customer were able to come together and proactively solve the problem, the relationship stayed intact and, in fact, often improved.



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 **Opportunity**

- A Quality Spill is really another OPPORTUNITY to:
  - Exhibit who your company really is
  - Show why you deserve to be their customer
  - Why you should actually get an opportunity to grow more business with them.
- Consider these 10 best practices in working with customers through a quality spill.





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 **10 Practices to Engage During a Quality Spill**

**#1: Build Trust- Good Relationships are critical**





**#2: Be Honest**

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**10 Practices to Engage During a Quality Spill**

**#3: Responsiveness is important**



**#4: Take an entrepreneurial approach to problem solving**



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**10 Practices to Engage During a Quality Spill**

**#5: Listen to the customer's special requests and needs**



**#6: Don't waste time - make sure you are adding value**



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**10 Practices to Engage During a Quality Spill**

**#7: Communicate your thoughts and ideas clearly**



**#8: Go the extra mile**




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**10 Practices to Engage During a Quality Spill**

**#9: Exhibit dependability**



**#10: You must be credible**



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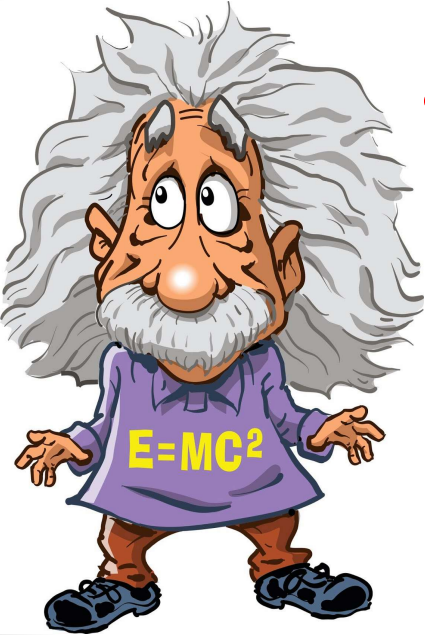


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## Asking the Right Questions

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If I had an hour to solve a problem, I'd spend 55 minutes thinking about the problem and 5 minutes thinking about solutions. – Albert Einstein

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## Fix That!

- Which is easier to solve?
  - Your car seems to have a low tire
  - Your car's right front tire is nearly flat on the ground



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## Fix That!




- Which is easier to solve?
  - The water is leaking in the sink
  - I've shut off the hot water knob of the bathroom faucet, but the water is still leaking.

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## Fix That!


- Which is easier to solve?
  - I can't believe it, what kind of supplier ships parts with no threads
  - In the last lot of parts you shipped us, Lot #12345, we found 4 parts missing the thread. It wasn't so bad because they were completely blank and we had no way to assemble them.



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## Ask Questions


- Get the part number
  - Preferably your part number
  - The customer's part number should work though
- Part description
  - This should help to determine if it is your part or not



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## Ask Questions


- Request
  - Lot number
  - Date shipped
  - Copy of label and/or shipping documents
  - Purchase order number
- Find out when the parts were received and the quantity
  - Helps establish how long they have been out of your control
- Ask for a picture or sample of the part if there is any doubt whether it is your part or not.

**GET THE DETAILS**

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## Ask Questions

- After determining that a problem you own does exist, you should ask questions that:
  - Ascertain what happened
  - Ascertain the extent to which it is happening
- Get a detailed explanation of the problem
  - What is happening?
  - Under what circumstances?
  - This is important step because the customer can often be vague or misleading and you don't want to waste time or start down the wrong path
- Get the lot number or other identifying information
  - Will help with containment
  - Determine if you have parts in-stock to assess and test or will need to request samples

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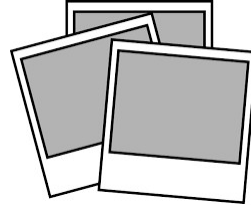
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## Ask Questions

- Request pictures to be sent immediately and followed with samples as quickly as possible.
  - Be prepared to turn-over an expedited shipping account.
- Determine scope of problem
  - How many bad parts found
  - What percent this is of the lot
  - How many parts have been made using suspect parts
  - If there is already a containment protocol that has been triggered
- Ask about how you can help with short-term containment
  - On-site sorting
  - Return for rework or sorting
  - Remake parts
  - Ship out certified stock
  - At this step you should also be looking whether stock is soon to be depleted and a supply shortage is likely



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## Minimizing Dead-Ends

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## In-Person Review


- Send a representative to review the problem first-hand
  - Sends a strong message of engagement
  - Will see things that the customer will not (especially relative to their process)
  - Builds credibility and trust



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## Treat Problems Equally

- Treat ALL problems with equal importance
  - More difficult than it sounds
  - A seemingly insignificant problem can easily snowball into a significant one
  - Good practice to treat all customers with equal importance
  - Treat every problem with respect and assume it is a “ticking bomb” just waiting to explode



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## The Fastener is Always to Blame

- It seems that the fastener supplier is always the first one blamed
- More problems are outside the supplier's control than are within their control
  - Improper design
  - Improper installation
- Realization of this will help the savvy supplier to formulate diplomatic ways to focus attention where it belongs



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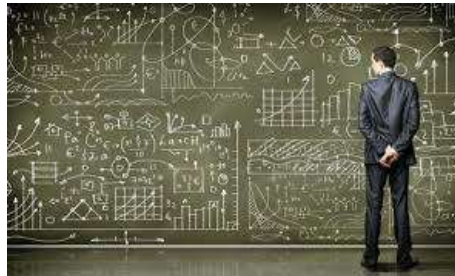
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## Challenge What Does Not Make Sense


- Challenge conclusions that don't make sense
  - If it doesn't make sense or agree with your experience- CHALLENGE IT!
  - Even an "expert" might NOT be expert on this problem.




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## Part 10: Finding the Root Cause



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## The True Root Cause

- The “true” root cause is the cause that once removed from the problem fault sequence prevents the final undesirable event from recurring.
- Opposed to a Causal Effect
  - Something that affects an event’s outcome but is not the initiating factor or root cause
  - Removing it can benefit the outcome BUT does not prevent a reoccurrence for certain
- Ultimately, the GOAL of all your problem-solving activity is to determine the “True” Root Cause



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## Example of a Causal Factor

- Example:
  - I recently replaced my tires. A causal factor was a slight out-of-alignment condition due to a loose control arm. The root cause though was normal wear gained by driving 80,000 miles.



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## Post hoc ergo propter hoc


- Latin for “after this, then because of this”
- Don't fall in this trap when arriving at a root cause
- An association with a particular event prior to the problem does not necessarily mean that it was the root cause
- When searching for the root cause- dig deep, and rely on facts and data



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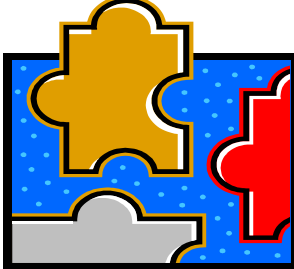
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## Root Cause Types


- Root Causes usually fall into one of three classifications:
  - Physical Causes- material failed, something stopped working
  - Human Causes- person(s) made a mistake or failed to react correctly
  - Organizational Causes- system, process, or policy is faulty



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## Considerations Related to Root Cause Analysis

- The primary aim of root cause analysis is to identify the factors that resulted in the harmful outcome in order to identify what needs to be changed to prevent reoccurrence of similar harmful outcomes in the future.
  - Factors related to the harmful outcome: the nature, magnitude, location, and timing
  - Identify changes: behaviors, actions, inactions, or conditions
  - "Success" is defined as the near-certain prevention of recurrence.
- To be effective, root cause analysis must be performed systematically.
- Usually a team effort is required.

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## Considerations Related to Root Cause Analysis

- There may be more than one root cause for an event or a problem. It takes diligence and patience to determine them all.
- The purpose of identifying all solutions to a problem is to prevent recurrence at lowest cost in the simplest way.
- Root causes usually cannot be adequately identified without a good definition of the problem.
- To be effective, the analysis should establish a sequence of events or timeline to understand the relationships between contributory (causal) factors and root cause(s).
- Root cause analysis can help transform a reactive culture into a proactive culture that solves problems before they occur or escalate. More importantly, it reduces the frequency of problems that occur.

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## Root Cause Examples

- What is wrong with the following Root Causes?

- Problem: The box was mislabeled
- Root Cause: A temporary worker was assigned to pack these boxes and placed labels from the previous lot of parts on the boxes by mistake.

- Problem: Customer was unable to assemble parts because they were missing threads
- Root Cause: When loading blanks into the hopper at rolling, parts spilled over the edge and got comingled with good parts at the exit chute of the machine.

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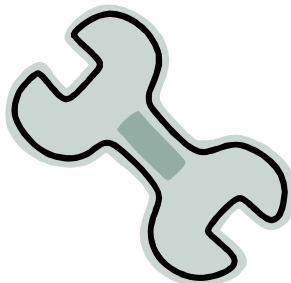
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## Root Cause Analysis Tools

- Pareto Analysis
- Ishikawa Diagram
- 5 Why Analysis
- FMEA
- Process Mapping
- Time Line



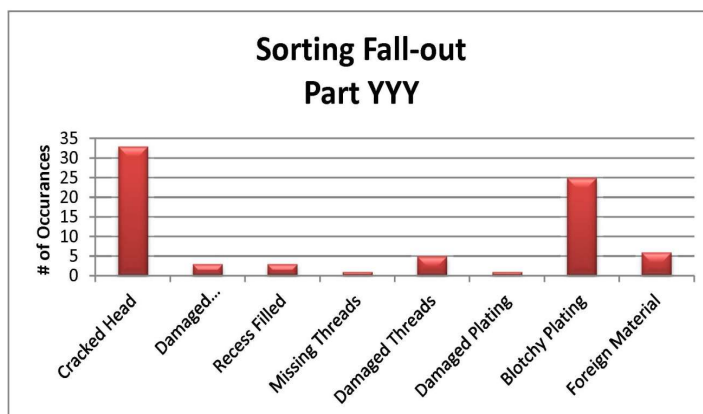
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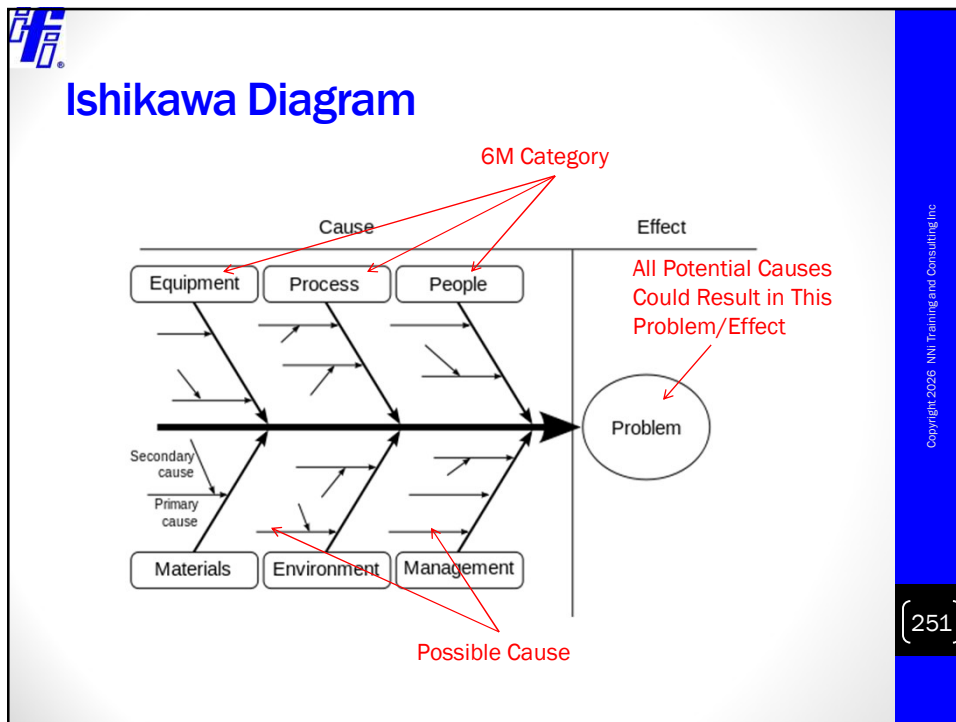
## Pareto Analysis



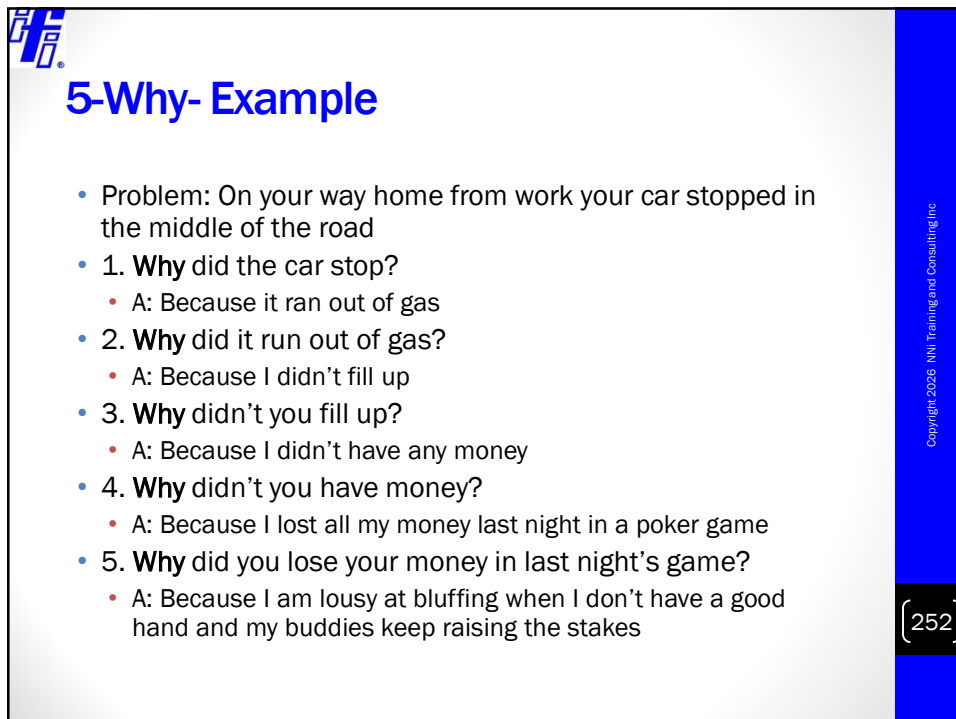
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