INTERNATIONAL FASTENER EXPO2025

PRECISION THREAD ROLLING PROCESS

FUNDAMENTALS, METHODS, CHALLENGES, AND VALUE-ADDED ADVANCES IN TODAY'S FASTENER MANUFACTURING INDUSTRY

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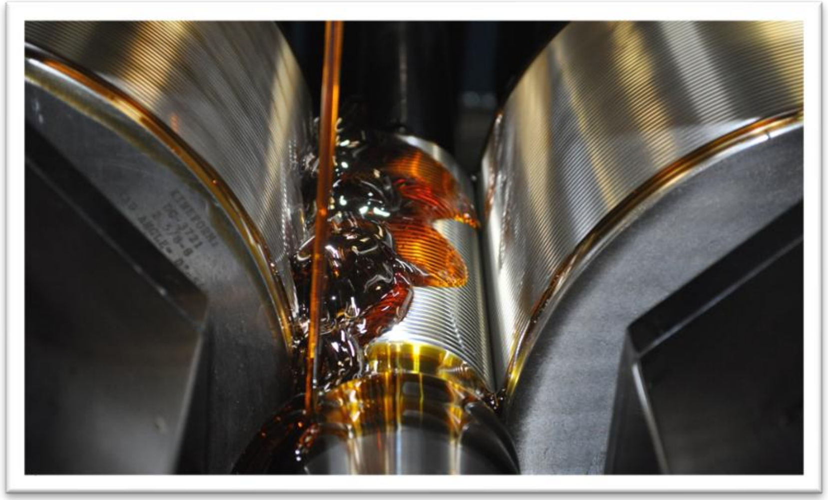
INTRODUCTION

PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

- **Thread rolling plays one of the most critical roles in fastener manufacturing.**
- **High efficiency, high precision, and with beneficial mechanical properties.**
- **Been in use since the mid-1800’s but has rapidly advanced during the last half century.**
- **Methods, machinery, and tooling have evolved along with process control, process monitoring, automation.**
- **The “black art” has been transformed into a highly controlled manufacturing process.**
- **Demands for higher strength fastener materials and thread rolling after heat treatment poses challenges.**
- **An understanding of the fundamentals, good design practices, and taking advantage of the latest tools and techniques can help improve process control, quality, and efficiency.**



Images – Kinefac Corporation

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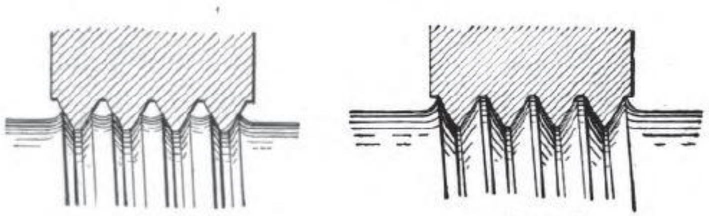
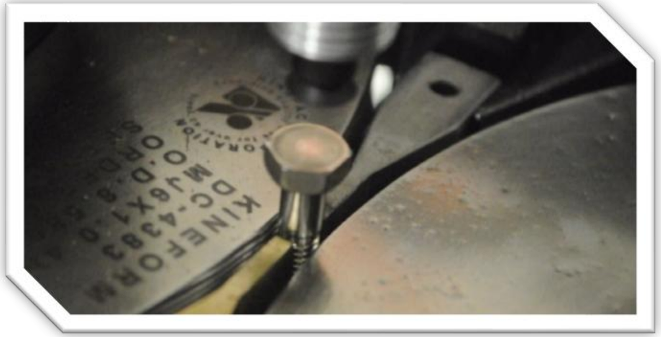
TODAY'S DISCUSSION

PRECISION THREAD ROLLING PROCESS

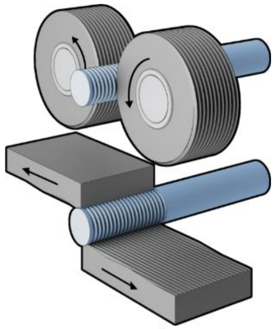
- Process Defined
- How it Works & Benefits
- How it's Carried Out
- Brief History & Evolution
- Today's Challenges
- Advances in Machinery & Tooling
- Good Design & Process Practices
- Wrap-Up Q&A



[1] Adapted from: The Art of Screw Thread Rolling - EJ Manville Co - 1906



Kinefac Corporation MC-15 FI (V) CNC PowerBox KineRoller



[2] https://www.manufacturingguide.com/en/thread-rolling

Kinefac Corporation MC-40 FI (V) CNC PowerBox KineRoller with Robot Load Induction Heating System

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PROCESS DEFINED

PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

- **A forming process whereby a helical, axial, or annular profile such as a thread, spline, or groove, is formed in the surface of a cylindrical blank by the phased interaction of flat or cylindrical dies.**

  H. Greis, N. Greis, Garniewicz, Willens
  McGraw-Hill Manufacturing Engineering Handbook, 2015

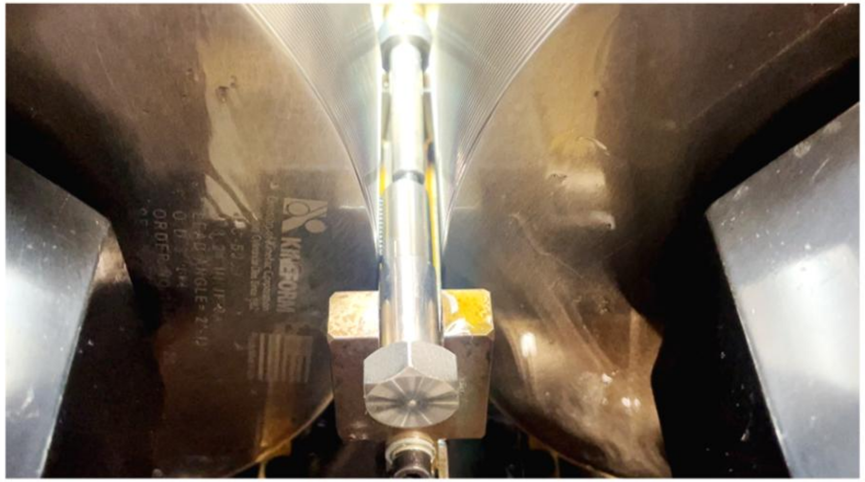
- **Dies have reverse form on their surface and simultaneously rotate and penetrate the blank at nearly the same surface velocity while forcing the blank material to displace outward from its surface to fill the die geometry.**

- **Dies are penetrated until enough material is displaced from the blank into the die geometry to achieve the desired level of profile fill and dwell revolutions are used to round the form.**

- **Constant volume process.**

- **Continuous but intermittent forging process.**

- **Carried out at room temperature (cold forming) or elevated temperature (warm forming).**



Kinefac Corporation 2-Die Infeed Thread Rolling

[3] YouTube – Office ONY – Flat Die Thread Rolling - https://www.youtube.com/watch?v=3R6jciGf0Dw

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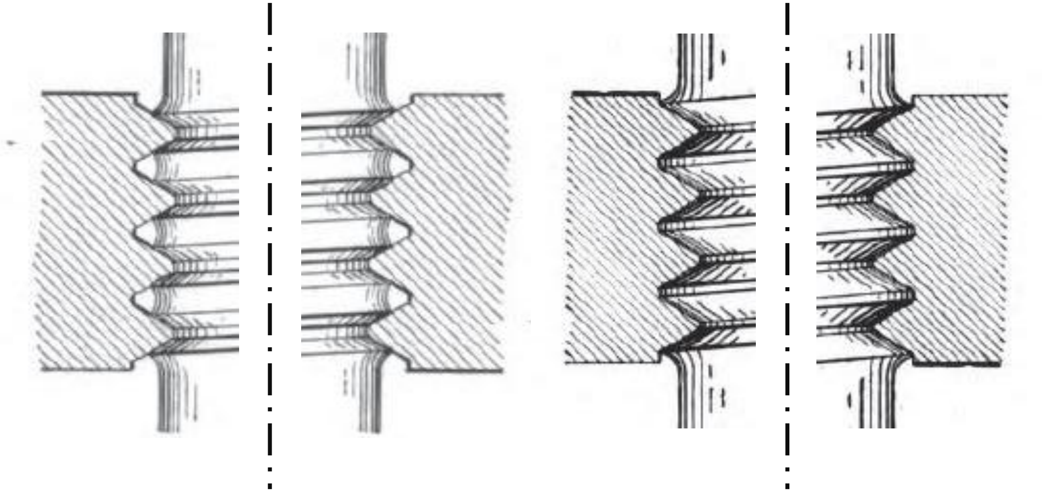
PROCESS DEFINED

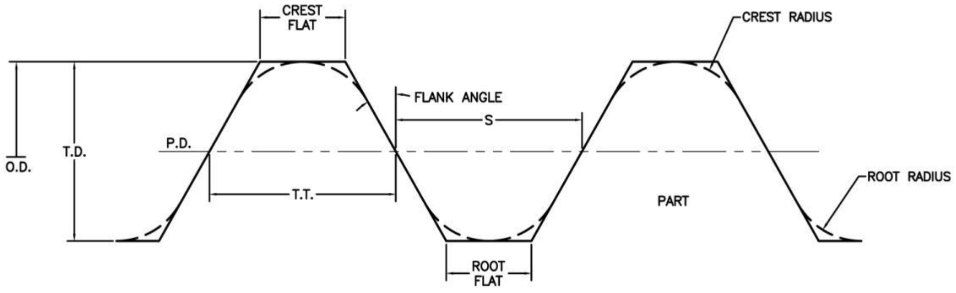
PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

- Part root diameter generated by die major diameter.
- Part major diameter generated by radial growth from blank based on degree of die penetration.
- Part pitch diameter (and root diameter) directly proportional to die penetration.
- Part major, pitch, and root diameters controlled by die geometry in a "full" condition.
- Rolled profile geometry (tooth thickness, tooth space, root radius, crest radius, flank angles) generated by die geometry.
- Part pitch / lead generated by die geometry, temperatures, and process.



[1] Adapted from: The Art of Screw Thread Rolling - EJ Manville Co - 1906



Thread Form Diagram - Kinefac Corporation

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ROLLABLE FORMS

PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

- Helical, axial, annular forms in continuous rod lengths or specific lengths on a part.
- HELICAL FORMS
    - Curved form on cylindrical surface such as threads, worms, serrations, knurls, and splines.
- AXIAL FORMS
    - Straight form on cylindrical surface parallel to the cylinder axis such as serrations, knurls, splines.
- ANNULAR FORMS
    - Ring-shaped form on cylindrical surface perpendicular to the cylinder axis such a flanges, grooves, chamfers, raceways.

[4] Adapted from: McGraw Hill Manufacturing Engineering Handbook – Chapter 26 Rolling Process – Kinefac Corporation

Rolled Part Examples Image – Kinefac Corporation

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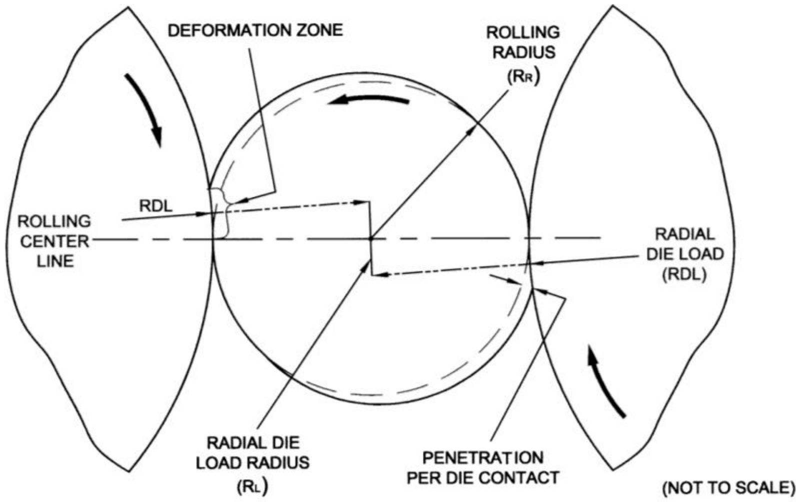
HOW IT WORKS

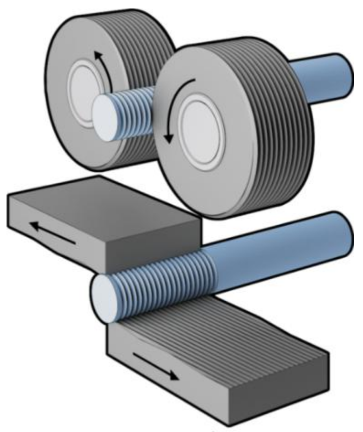
PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

- **Simultaneous interaction of:**
  - **Friction**
  - **Surface Pressure**
  - **Continuous Plastic Deformation / Material Flow**
  - **Energy Transfer**
- **<u>Friction</u> at die / part interface allows dies to grip & rotate blank at about the same surface velocity.**
- **<u>Surface pressure</u> generated by forcing dies radially against the blank.**
- **<u>Plastic deformation</u> when there's enough surface pressure to yield the blank and form a new permanent shape.**
- **<u>Material flow</u> occurs when blank material continuously deformed (plasticized) and guided into shape.**
- **<u>Energy</u> required to continuously overcome resistance to plastic deformation (yielding strength) for material flow.**
- **Ability to roll controlled by ability to transfer energy through dies into blank without causing blank to slip, stall, or fail**



[5] Adapted from: McGraw Hill Manufacturing Engineering Handbook – Chapter 26 Rolling Process – Kinefac Corporation



[2] https://www.manufacturingguide.com/en/thread-rolling

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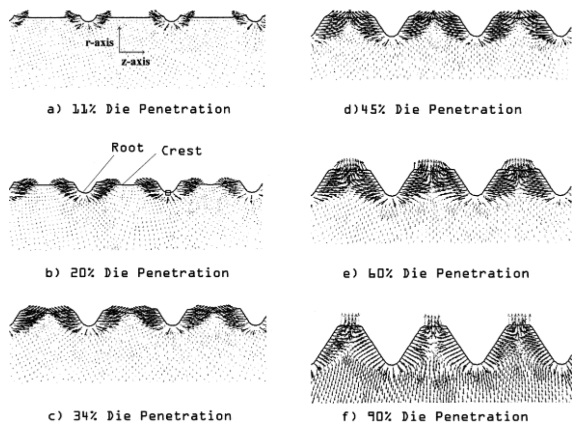
HOW IT WORKS

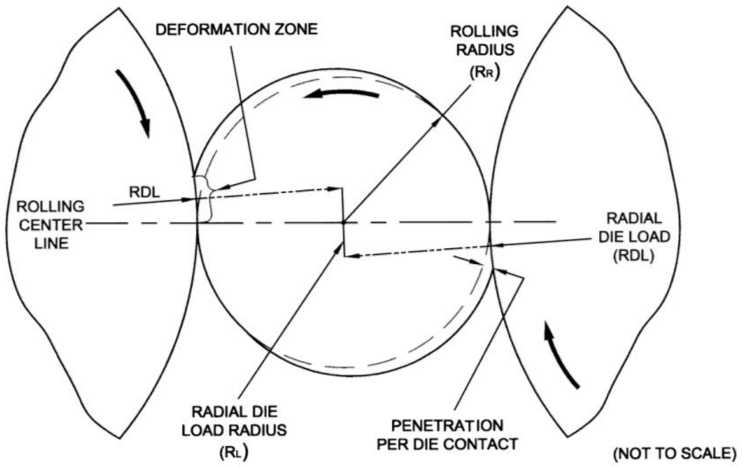
PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

- **Material flows in direction / path of least resistance.**
- **Die geometry generally dictates initial and final direction and path as material slides on the die surfaces.**
- **Forming wave ahead of each die in convergence zone during penetration.**
- **Size of forming wave governed by rate of penetration and geometry of die profile.**
- **Part is non-round during penetration phase.**
- **Forming wave must be ironed out using dwell revolutions when penetration stopped.**
- **Lack of dwell at end of penetration can result in non-round rolled form.**



[6] Adapted from: Domblesky & Feng 2002



[5] Adapted from: McGraw Hill Manufacturing Engineering Handbook – Chapter 26 Rolling Process – Kinefac Corporation

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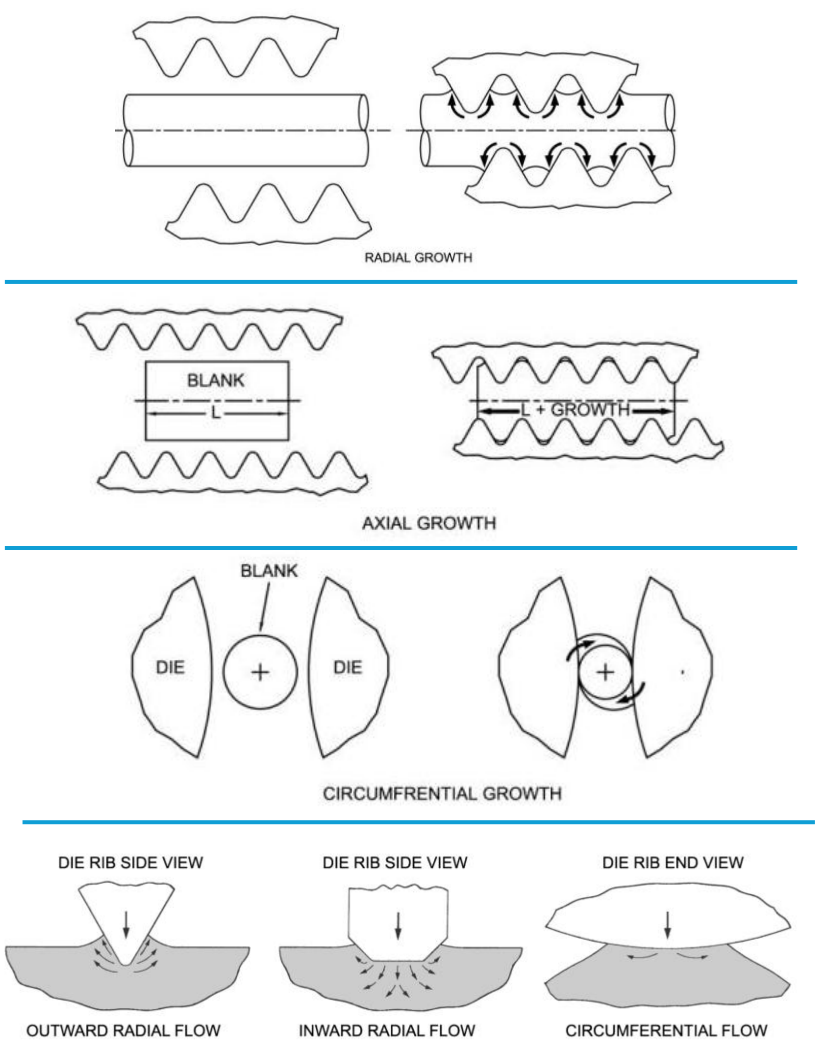
HOW IT WORKS

PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

- **RADIAL FLOW**
  - **Outward from blank centerline causing workpiece to increase in diameter.**
  - **Driven by wedge action of dies and path of least resistance.**
- **AXIAL FLOW**
  - **Along blank axis causing workpiece to increase in length.**
  - **Driven by broad shaped or deep profiles that force more inward flow.**
- **CIRCUMFERENTIAL FLOW**
  - **Around the outer surface of the workpiece usually resulting in flaking / tearing at surface.**
  - **Caused by over-rolling or high penetration and detrimental to die life.**



Growth Directions Diagrams – Kinefac Corporation

[7] Adapted from: McGraw Hill Manufacturing Engineering Handbook – Chapter 26 Rolling Process – Kinefac Corporation

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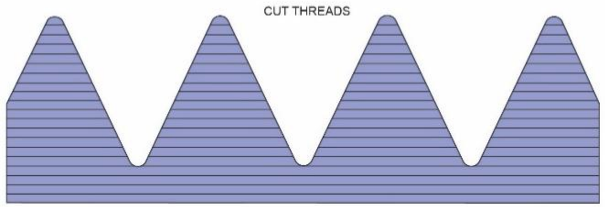
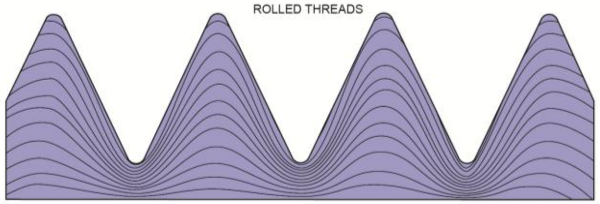
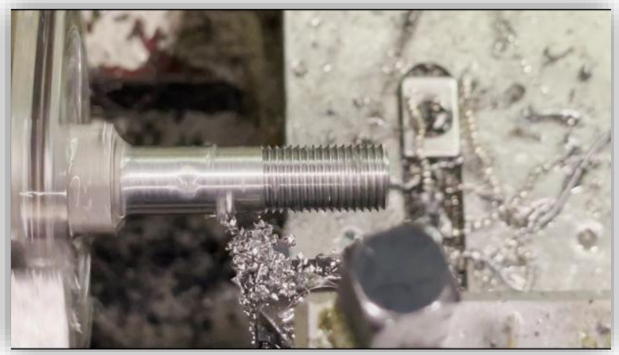
BENEFITS OF THREAD ROLLING

PRECISION THREAD ROLLING PROCESS

- **High Speed**
- **Improved Strength**
- **Superior Surface Finish**
- **Material Savings**
- **Outstanding Repeatability**
- **Simpler Setup**







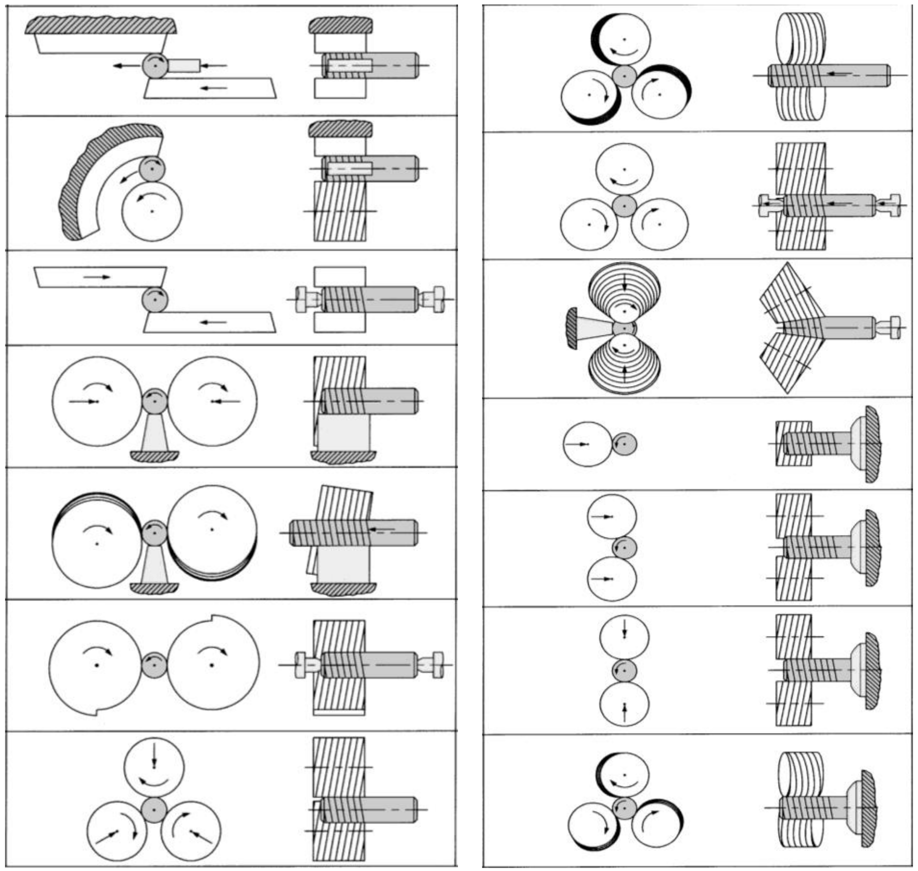
Diagrams, Images, Video - Kinefac Corporation

HOW IT'S CARRIED OUT

PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

- Two main categories of roll-forming systems.
  - Flat Die
  - Cylindrical Die
- Different variations of each system.
- Dedicated machinery or attachments.
- Various types of rolling depending on system.
  - Infeed, Throughfeed, etc.
- Each system has its advantages.
  - Speed, part size, material, geometry, hollow vs. solid, etc.



[8] Adapted from: McGraw Hill Manufacturing Engineering Handbook – Chapter 26 Rolling Process – Kinefac Corporation

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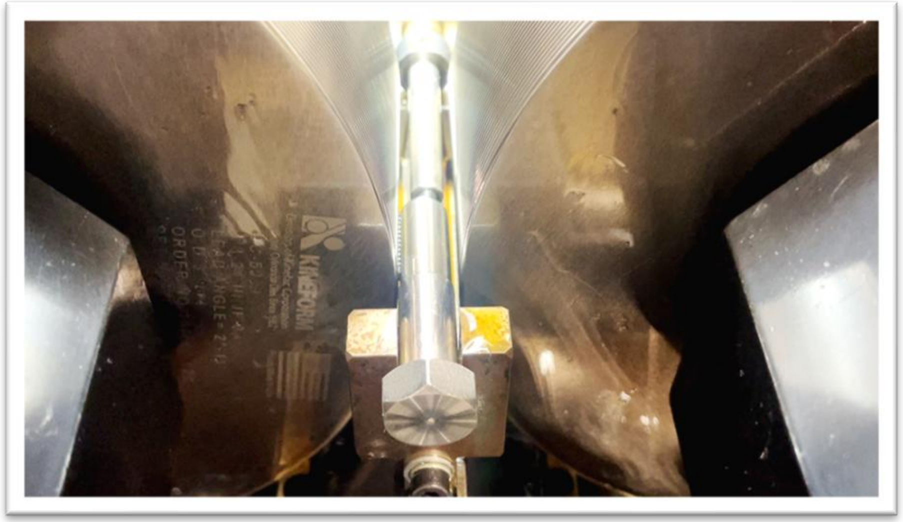
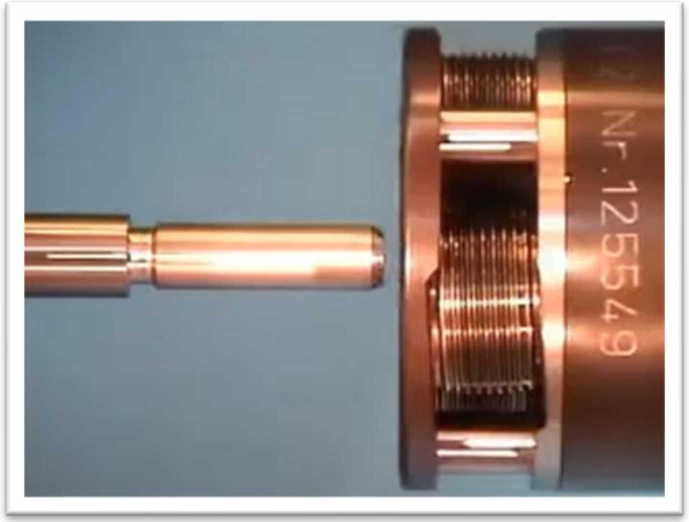
HOW IT'S CARRIED OUT

PRECISION THREAD ROLLING PROCESS



Kinefac Corporation 2-Die Infeed Thread Rolling



[31] YouTube – DGISupplyMarketing - End Feed Attachment- https://www.youtube.com/watch?v=rt8VfgfWa54

[3] YouTube – Office ONY – Flat Die Thread Rolling - https://www.youtube.com/watch?v=3R6jciGf0Dw

[32] YouTube – goral61–Planetary Die Thread Rolling - https://www.youtube.com/watch?v=Hr14SrAKBl0&t=12s

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HOW IT'S CARRIED OUT

PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

FLAT DIE

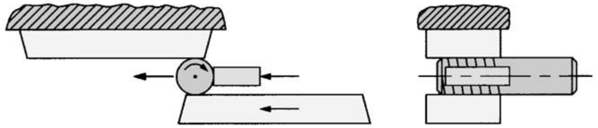
- Dies have starting taper, dwell, and exit taper.
- High production rates possible (up to 800 PPM or more).
- Common for standard solid fasteners <1-inch diameter.
- Multiple forms can be rolled on a blank by stacking dies.

CYLINDRICAL DIE

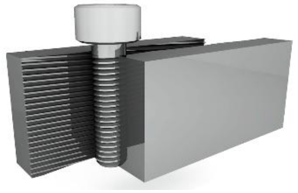
- Infeed dies are round for infinite work revolutions.
- Throughfeed dies have starting taper, dwell, and exit taper.
- Production rates typically <60 PPM (infeed).
- Common for solid and hollow fasteners up to ~6-inch+ diameter, limited by machine tonnage / attachment capacity.

PLANETARY DIE

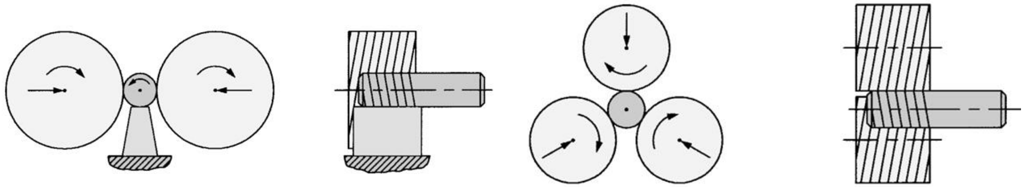
- One round die and one segment die.
- Die gap sets penetration and dwell.
- High production rates possible (up to 800 PPM or more).
- Common for standard solid fasteners <½-inch diameter.



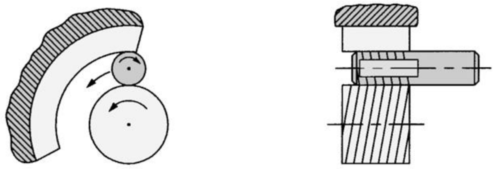
[9] Adapted from: McGraw Hill Manufacturing Engineering Handbook – Chapter 26 Rolling Process – Kinefac Corporation



[10] Adapted from: https://www.iqsdirectory.com/articles/screw-machine-product/thread-rolling.html



[11] Adapted from: McGraw Hill Manufacturing Engineering Handbook – Chapter 26 Rolling Process – Kinefac Corporation



[12] Adapted from: McGraw Hill Manufacturing Engineering Handbook – Chapter 26 Rolling Process – Kinefac Corporation

[13] Adapted from: https://www.iqsdirectory.com/articles/screw-machine-product/thread-rolling.html

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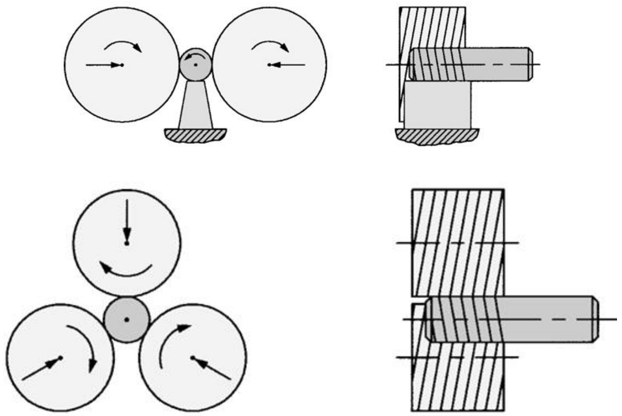
HOW IT'S CARRIED OUT

PRECISION THREAD ROLLING PROCESS

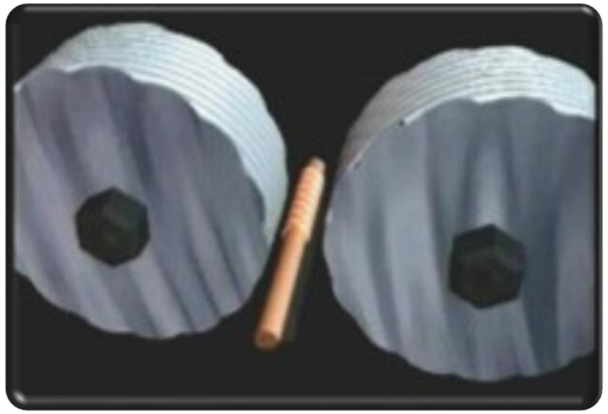
Kinefac Corporation MC-200 FT/I (H) PowerBox KineRoller

Kinefac Corporation MC-9 HD FI (V) KineRoller

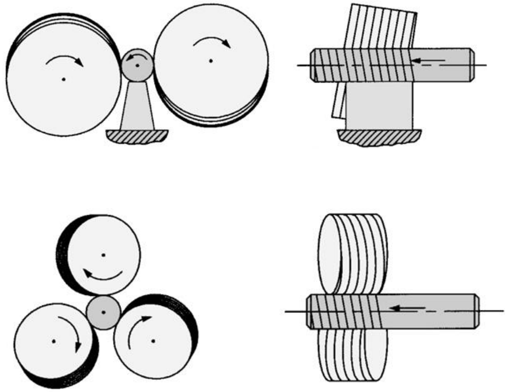
INFEED



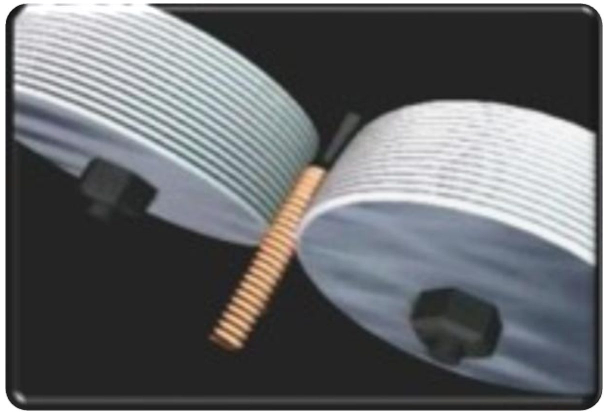
[14] Adapted from: McGraw Hill Manufacturing Engineering Handbook – Chapter 26 Rolling Process – Kinefac Corporation



THROUGHFEED



[15] Adapted from: McGraw Hill Manufacturing Engineering Handbook – Chapter 26 Rolling Process – Kinefac Corporation



Animations – Kinefac Corporation

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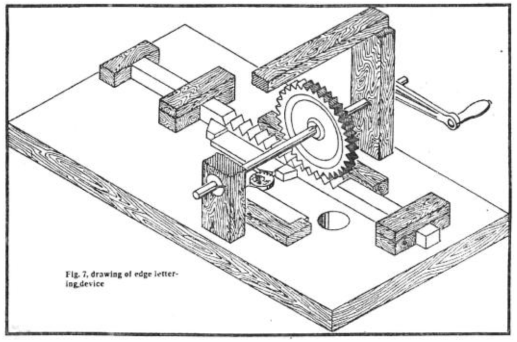
HISTORY & EVOLUTION

PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

- **Simple ancient craft of pottery making 20,000+ years ago mimics the rolling process used today in metals.**
- **Potter would roll a piece of clay between their hands to change its cylindrical shape. Pressing hands hard enough results in forcing some clay squeezing out between the fingers, resembling ridges like a screw thread.**
- **Applying this to a metal working process for rolling screw threads would not come until the 1830's.**
- **In between in the mid-1600's thievery brought about coin edge lettering which was achieved by hand operated opposing flat racks to roll ridges on edges of coins.**
- **1831 earliest known patent for screw thread rolling a.k.a. "screw thread swaging" covering flat die & planetary die by Hazard Knowles in Colchester, CT, USA for making wood screws, carriage bolts, stove bolts.**

[16] http://pottery-and-ceramics.blogspot.com/2010/06/beginners-guide-to-art-of-ceramics-coil.html
[17] https://www.firstpalette.com/craft/name-clay-keychain.html



[18] Coin World 1983 – Edge Lettering Machine

[19] https://www.researchgate.net/post/Screw_manufacturing_by_thread_rolling_with_flat_dies

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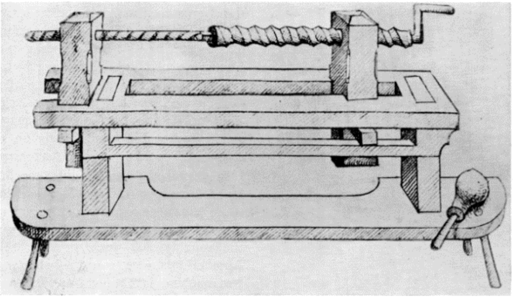
HISTORY & EVOLUTION

PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

- **1500’s to 1700’s screws were cut or filed by hand.**
- **Mid-1700’s mechanized screw cutting machinery.**
- **1790’s first “modern” power driven screw cutting machine lathe – Henry Maudslay - England.**
- **1800’s marked birth of machine tool industry as industrial revolution ramps up and the need for more precision threaded fasteners increases drastically – steam engines, mfg. machinery.**
- **Early 1800’s Northeast USA dominated screw manufacturing and put Providence, RI on the map. Most companies developed and made their own screw cutting machinery or licensed technology.**
    - 1810 Abom & Jackson – Providence, Rhode Island
    - 1830’s C. Read & Co. – Providence, Rhode Island / Worcester, MA
    - 1838 Providence Screw Co. (organized from C. Read & Co.)
    - 1838 Eagle Screw Company – Providence, Rhode Island
    - 1840 Rugg & Barnes – Plantsville, CT
    - 1850 New England Screw Co. – Providence, Rhode Island
    - 1860 American Screw Co. – Providence, Rhode Island (merging of Eagle Screw Co. & New England Screw Co.)



[20] https://freechaptersinbooks.wordpress.com/2012/09/18/screw-thread-cutting-by-the-master-screw-method-since-1480/

[21] http://www.edubilla.com/invention/screw-cutting-lathe/

[22] https://www.worthpoint.com/worthopedia/wood-crate-american-screw-co-providence-ri

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HISTORY & EVOLUTION

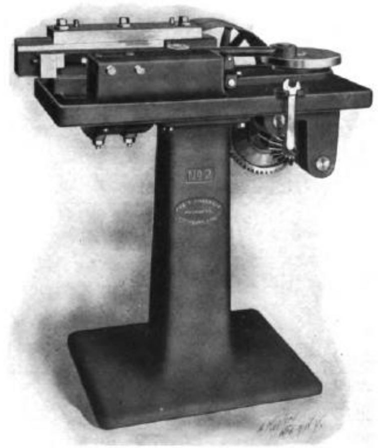
PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

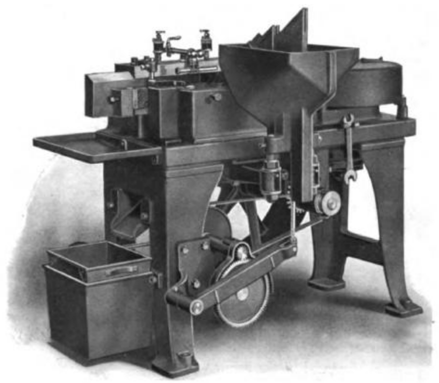
- **Mid to late 1800's screw thread rolling was highly experimental, low precision.**
- **No formal machine builders or die makers existed yet.**
- **Steels for screw blanks and dies were not well developed for cold working which resulted in cracking, splitting, folding, and poor die life.**
- **Die manufacturing limited accuracy and quality of threads that could be achieved.**
- **1880's thread rolling machines start becoming commercially available (flat die mainly) and thread rolling starts getting used in regular production.**
- **Was still considered a crude, high production process for low-precision fasteners and was mostly unknown outside of fastener industry before WWI & WWII. Engineers were trained to avoid it.**
- **Thread rolling machinery (flat die) was limited in what could be rolled prior to the 1930's.**

[26] A.B. Reed – Historical Sketch

[23] Adapted from: The Art of Screw Thread Rolling - EJ Manville Co – 1906 – Rolled Thread Screws



[24] Adapted from: The Art of Screw Thread Rolling - EJ Manville Co – 1906 – No. 2 Machine



[25] Adapted from: The Art of Screw Thread Rolling - EJ Manville Co – 1906 – No. 3 Machine

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HISTORY & EVOLUTION

PRECISION THREAD ROLLING PROCESS

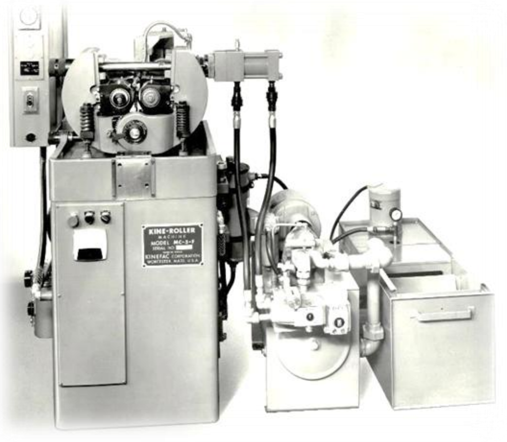
THREAD & FORM ROLLING

- **WWI & WWII changed things rapidly in the 1920's / 1930's.**
- **Need for smooth, accurate, high strength aircraft bolts in high volume.**
- **Better cold forming steels being developed and higher precision dies being made.**
- **The need for rolling higher hardness, larger diameter, & hollow parts on all types of components lead to development of commercially available cylindrical die machines (mainly 3-die & then 2-die) in late 1930's.**
- **Use of thread rolling on precision aircraft fasteners in both World Wars strengthened its reputation as a precision manufacturing process.**
- **Became preferred method of threading highest quality products and is still regarded as fastest most economical method of forming screw threads.**
- **Used to produce most of the world's machine screws, cap screws, wood screws, lead screws, large precision fasteners.**

[26] A.B. Reed – Historical Sketch

[27] https://www.nationalmuseum.af.mil/Visit/Museum-Exhibits/Fact-Sheets/Display/Article/858881/pre-war-super-bombers/

[28] https://www.cnclathing.com/guide/fasteners-used-in-aerospace-types-materials-characteristics-of-aircraft-fasteners-cnclathing



[29] Kinefac Corporation MC-5 FT/I KineRoller

[30] Adapted from: Reed Rolled Thread Die General Bulletin 5-5C-1-ME-173-A

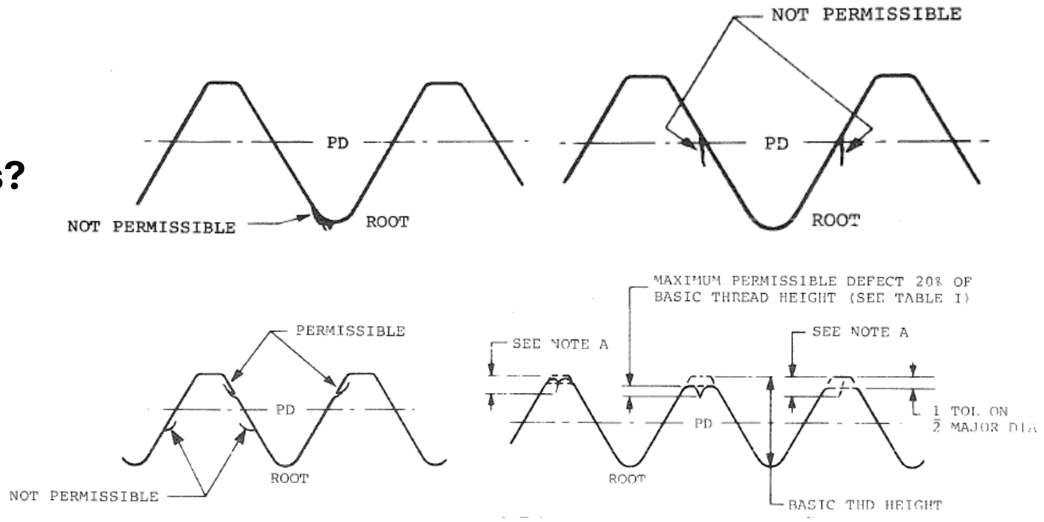
TODAY’S CHALLENGES

PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

- **Drivers / Trends**
  - Fastener materials and hardness levels.
  - Blank configurations.
  - Varied production demand requirements.
  - Non-standard thread form geometries / shapes.
  - Stringent quality requirements.
  - Shortage of skilled labor.
- **What does this mean for thread rolling users?**
  - Increased setup difficulty.
  - Die life concerns.
  - Frequent changeovers.
  - Increased need for process traceability.
  - Increased need for push-button setup.

Images – Kinefac Corporation



[31] Adapted from: AMS 7467A

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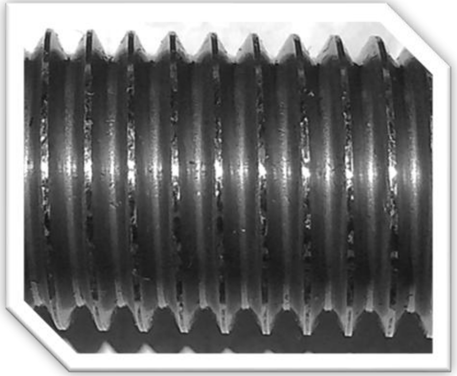
TODAY'S CHALLENGES

PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

- **Exotic alloys like Inconel, Titanium, Hastelloy, Waspaloy, A286, and PH SS's typically have high tensile strengths and work-hardening sensitivity.**
  - Aerospace, nuclear, and power gen applications.
  - Challenging for die life.
  - Forming difficulty in thread crests with traditional carbide blades – galling, scuffing, etc.
- **More traditional alloys like 4140 and B7 and 300-series SS's are presenting more at the high end of tensile strength requirements.**
  - Anchor bolts in construction and oil & gas.
  - Challenging for die life where straightness and roundness of blanks is not as stringent.
  - Stainless steels present forming difficulty with traditional carbide blades – galling, scuffing, etc.
- **Pre-roll blanks with short undercuts, steep chamfers, hollow features, or shoulder features require careful setup and can be challenging for die life.**


Images – Kinefac Corporation

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TODAY'S CHALLENGES

PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

- Today's trends of on-demand manufacturing and small lot sizes require frequent changeovers and careful setup which can be time consuming & costly.
- Non-standard or compensated thread forms with expanded or contracted leads require engineered dies.
- Thread crest fullness requirements, roundness, straightness, drunkenness, laps, seams, and form deviations need careful setup and can impact die life.
- Due to the critical application of some fasteners increased process traceability is needed.
- Thread rolling has traditionally required some process knowledge to be successful. Shortages of skilled labor and high turnover are challenging.

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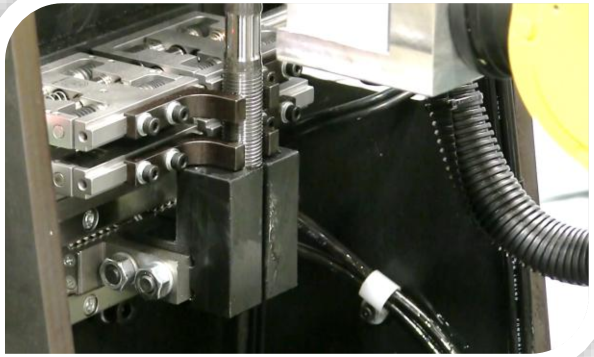
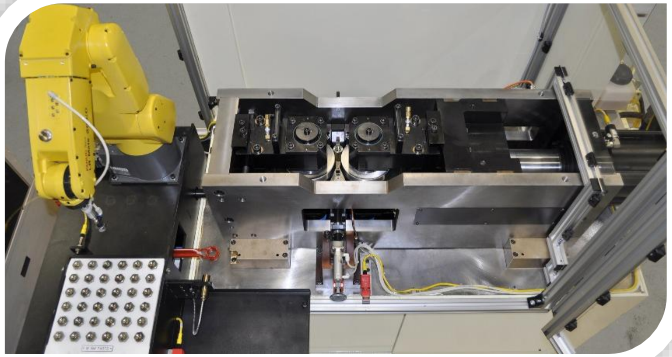
ADVANCES IN MACHINERY / TOOLING

PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

- **Servo control technology has greatly simplified setups, reduced some of the need for senior level skill, improved quality.**
- **Work rest blades made of low-friction gall-resistant materials allow materials to be rolled with clean crests – especially coupled with servo blade supports.**
- **Integrated features such as induction heating with consistent temperatures and timing allow high-tensile alloys to be rolled with improved quality and reduced impact on die life.**
- **Integrated in-process gaging and inspection with data capture is allowing for increased traceability and more efficient quality control.**
- **Tool steel optimization of hardness, toughness, and wear resistance along with surface treatments and coatings is allowing dies to last longer and be economically matched to the application.**





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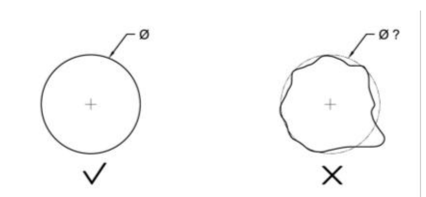
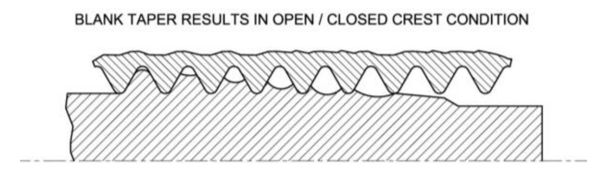
SOLUTIONS / BEST PRACTICES

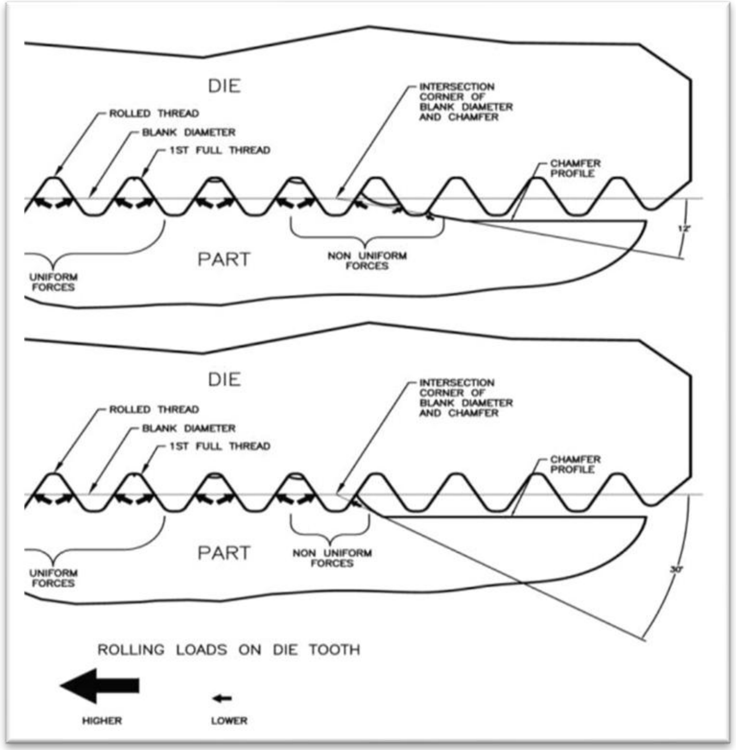
PRECISION THREAD ROLLING PROCESS

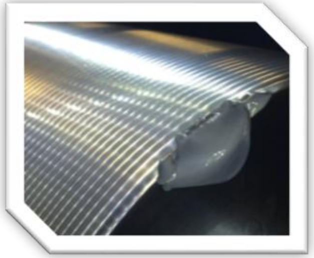
THREAD & FORM ROLLING

- **Review each critical part of the process to set yourself up for maximized success.**
- **Work with your customers on design flexibility and educate them on best practices.**
- **BLANKS**
  - **Rolling will generally follow the blank!**
  - **Keep round, straight, and with minimal taper <.001-inch.**
  - **Use the lowest chamfer angles possible and start them at least .005” below root.**
  - **30° will roll up to ~45°.**
  - **Consider rolling a longer thread with low chamfers (15° to 20° for high hardness) and finish machine after.**









Diagrams & Images – Kinefac Corporation

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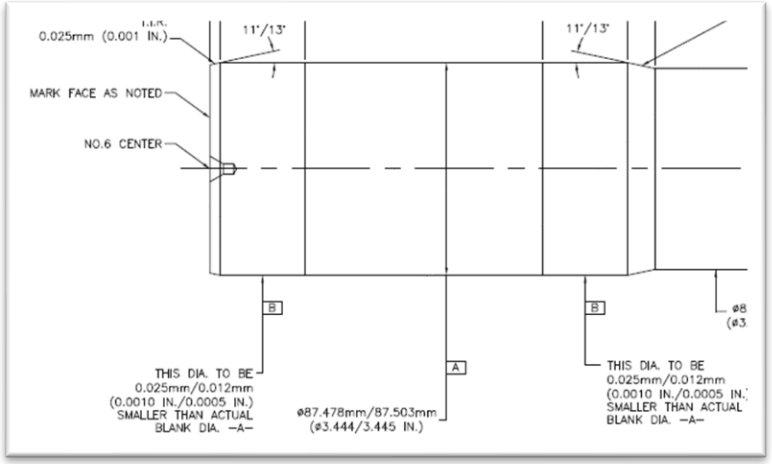
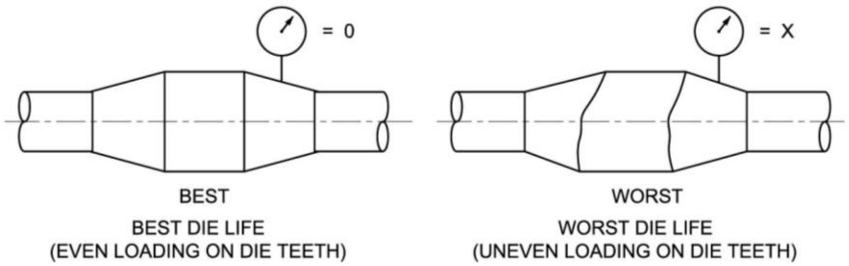
SOLUTIONS / BEST PRACTICES

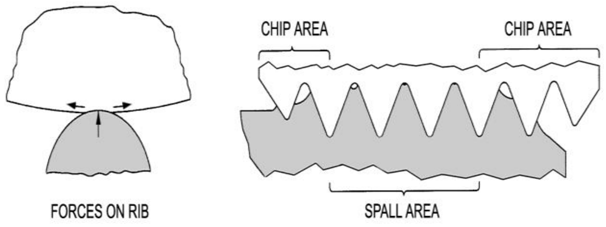
PRECISION THREAD ROLLING PROCESS

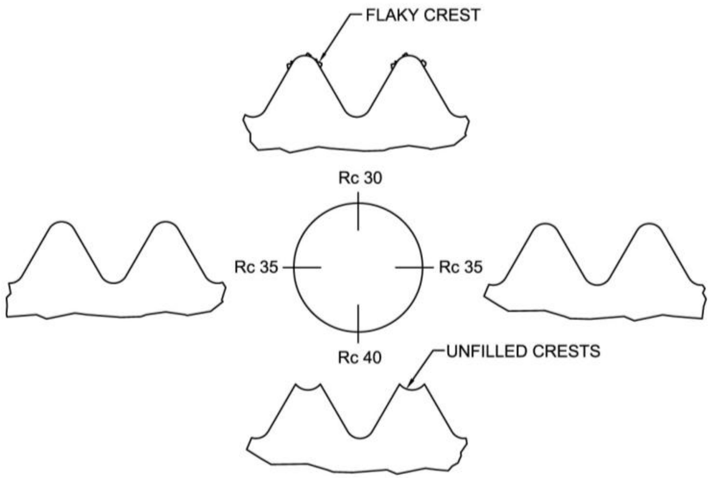
THREAD & FORM ROLLING

- **BLANKS**
  - **Keep concentricity of all diameters and chamfers to <.001-inch.**
  - **Keep hardness variation of a lot <3 points HRC.**
  - **Size your blank diameters for the correct amount of fill (with seam) to avoid over-rolling.**
  - **Consider profiling blanks when infeeding long threads to maintain fullness in the middle.**









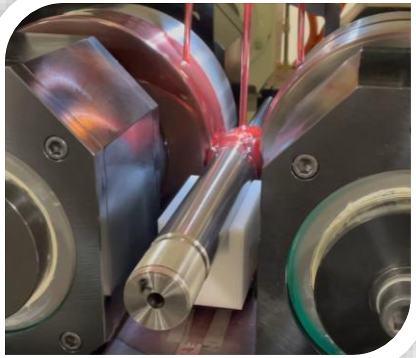
Diagrams & Images – Kinefac Corporation

SOLUTIONS / BEST PRACTICES

PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

- **DIES**
  - Balance hardness, toughness, and wear resistance.
  - Consider surface treatments and coatings.
  - Use double-face-width dies to maximize usage / reduce downtime.
  - Over-size infeed dies for increased regrinds (if feed ok).
  - Start with smallest die crest radius for high hardness rolling to maximize life. Tool steel does deform!
  - Consider helical versus annular designs for throughfeed where penetration rates and dwell can be optimized.
  - Implement lead or profile compensations to help gaging issues or to protect against over-roll. Warm rolling may require it!
- **TOOLING / BLADES**
  - Use low friction gall-resistant blade rest materials which with SS's, Titanium, and nickel-based alloys.
  - Consider roller blades for diameters over ~1-inch range.
  - Consider supporting on centers for high-end studs/shafts.
  - Avoid restricting rotation or side movements while rolling.



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SOLUTIONS / BEST PRACTICES

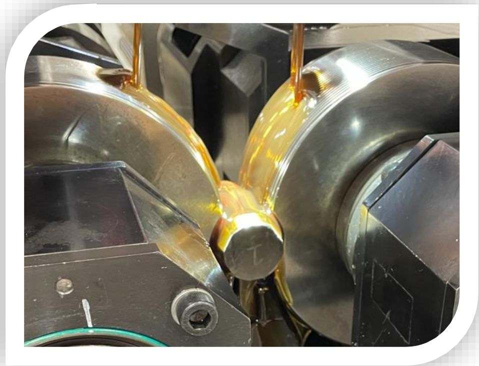
PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

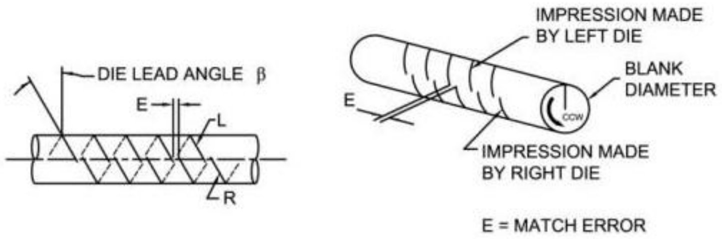
- **COOLANT / LUBRICATION**
  - Oil is generally best for tool life and finish results.
  - High pressure additives and good viscosity for coverage.
  - If using water soluble, maintain an appropriate mix ratio for lubricity and corrosion resistance.
  - Use chilling for high heat applications.

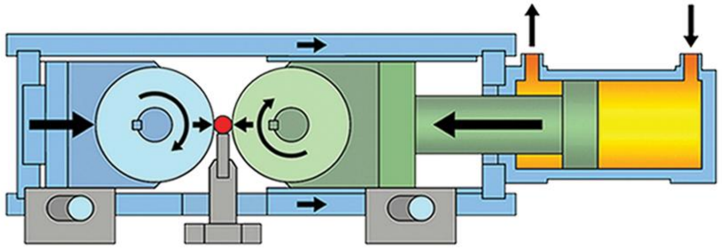
- **MACHINE / SETUP**
  - Make sure your machine or attachment is in good condition.
  - Use high stiffness machines with precision positioning systems to ensure consistent quality.
  - Ensure proper alignments of the dies, spindles, work support, and blank to minimize drunkenness, etc.
  - Keep die faces in line and spend time on a good die match via rotary alignment for helical die setups.
  - Run with open taper near inboard sections and chamfers.
  - If there is axial feed, feed inward where possible.
  - Use 3-dies for hollow / thin wall rolling and 2-dies for all else to maximize die size and more simplified setup.

[3] YouTube – Office ONY - Flat Die Thread Rolling https://www.youtube.com/watch?v=3R6jciGf0Dw



2-Die Infeed Thread Rolling – Kinefac Corporation





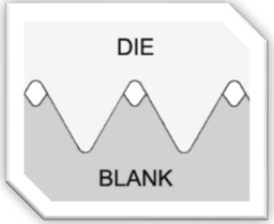
Die Match Alignment Diagrams – Kinefac Corporation
2-Die Rolling Structure - Kinefac Corporation

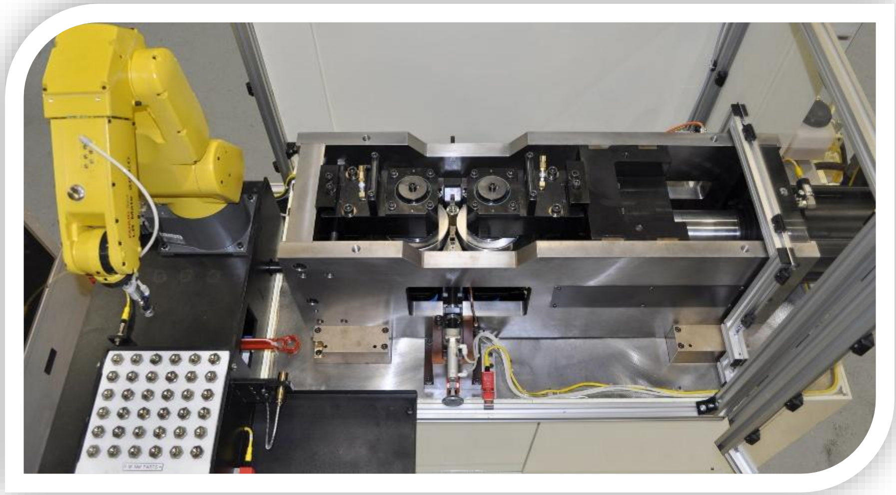
SOLUTIONS / BEST PRACTICES

PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

- **PROCESSING PARAMETERS**
  - **Avoid over-rolling to fully burnished crests.**
  - **Balance penetration rate with blank hardness and work-hardening sensitivity.**
  - **Penetration rates of .001 to .003-inch on diameter per part rev for higher hardness.**
  - **Minimize dwell revolutions to round part - 5 to 10 revs is usually plenty.**
  - **Monitor and capture die forces and positions for traceability.**
  - **Use high/low force set limits to detect over-rolling, incorrect blank size, incorrect blank hardness, or out of match conditions.**
  - **Use warm rolling (if allowed) to help improve material flow and reduce die stress. Keep heat and transfer times consistent.**
  - **Use robotic handling for operator safety and process consistency.**





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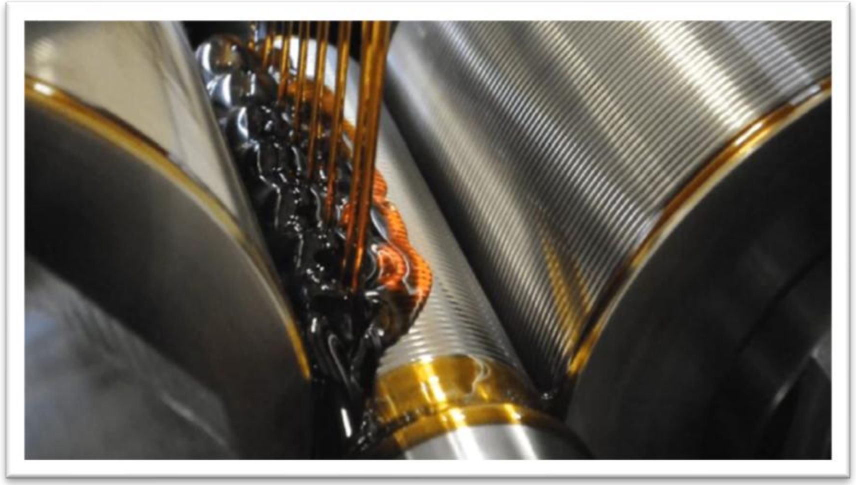
SUMMARY / WRAP UP

PRECISION THREAD ROLLING PROCESS

THREAD & FORM ROLLING

- Thread rolling will continue to be a critical part of fastener manufacturing.
- Limits will continue to be pushed.
- Give attention to each part of your process to set yourself up for maximized success.
- Work with your customers whenever possible on design flexibility and educate them on best practices.
- Work with your machinery and tooling manufacturers to stay current with the latest features and advances for setup, quality, and life improvements.



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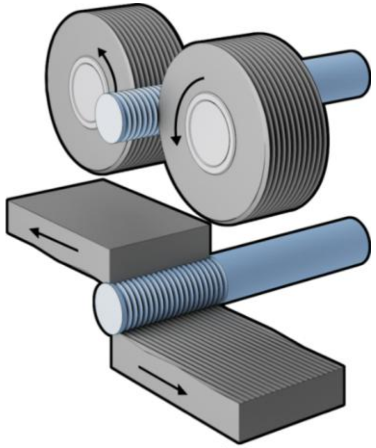

[2] https://www.manufacturingguide.com/en/thread-rolling

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Questions?

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Your feedback is greatly appreciated and helps provide us with first-hand insight that is carefully reviewed as we plan future IFE educational programs.

Thank you!

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