### FUNDAMENTALS OF TOOL DESIGN

Troubleshooting Tool & Die Making - TD

SCENE 1.

FTD01A, CGS: FBI warning white text centered on black to transparent gradient FTD01B, motion background

SCENE 2.

continue motion background FTD02A, CGS: disclaimer white text centered on black to transparent gradient

SCENE 3.

FTD03A, SME logo open, with music

SCENE 4.

FTD04A, FTD open, with music TD04B, edited peter carey narration

SCENE 5.

continue FTD open

TD05A, CGS: Troubleshooting Tool & Die Making

FTD05B, blue background FTD05C, sound slug

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Always read the operating manual and safety information provided by the manufacturer before operating any manufacturing equipment.

Make sure all machine guards are in place, and follow all safety procedures when working with or near manufacturing equipment.

### MUSIC UP AND UNDER

### NARRATION (VO):

THE FUNDAMENTALS OF TOOL DESIGN VIDEO SERIES, EXAMINING THE DIVERSE FIELD OF TOOL DESIGN MATERIALS AND TECHNOLOGIES.

## NARRATION (VO):

THIS PROGRAM EXPLORES THE FUNDAMENTALS white text, centered on background OF TROUBLESHOOTING TOOL & DIE MAKING, AND EXPLAINS HOW TO ANALYZE AND IMPROVE ON THE PRODUCTION PERFORMANCE OF TOOLING.

SCENE 6

TD06A, FTD30, 10:10:04:00-10:10:31:00 maintenance on die

TD06B, FTD28, 08:37:30:00-08:38:10:00

zoom in, stamping operation

SCENE 7.

TD07A, FTD95, 03:58:47:00-03:59:22:00

maintenance on die

TD07B, CGS: Tool Design

Material Selection

Machining Heat Treating Finish Machining

Maintenance

SCENE 8.

TD08A, FMP422, 16:07:06:00-16:07:19:00

 $\hbox{injection molding operation}\\$ 

TD08B, FMP906, 01:14:08:00-01:14:35:00

injection tool being repaired

TD08C, zoom out, still, failed tool

# NARRATION (VO):

TOOL AND DIE TROUBLESHOOTING GOES FAR
BEYOND ROUTINE MAINTENANCE AND REPAIR.
THE GOAL IS TO OPTIMIZE YOUR TOOLING
INVESTMENT BY BALANCING TOOLING COSTS
AGAINST THE EXPECTED RETURN ON
INVESTMENT.

#### NARRATION (VO):

THIS TASK BECOMES COMPLICATED AS THERE

ARE MANY ACTIVITIES INVOLVED, INCLUDING:

TOOL DESIGN, MATERIAL SELECTION,

MACHINING, HEAT TREATING, FINISH

MACHINING AND MAINTENANCE. ALL OF THESE

ACTIVITIES INTERACT TO AFFECT THE

OVERALL PRODUCTION PERFORMANCE OF A

TOOL.

#### NARRATION (VO):

BUDGETARY REQUIREMENTS AND TIME

CONSTRAINTS ALSO AFFECT THE SERVICE LIFE

AND PERFORMANCE OF A TOOL. KEEPING TOOL

COSTS TO A MINIMUM AT THE EXPENSE OF

TOOL PERFORMANCE CAN BECOME THE ROOT

CAUSE OF THOUSANDS OF DOLLARS OF

PRODUCTION DOWN TIME, POOR PART QUALITY,

SCRAP OR COSTLY MAINTENANCE. CLEARLY,

THE MOST EXPENSIVE TOOL IS THE TOOL THAT

FAILS PREMATURELY.

SCENE 9.

TD09A, FTD83, 13:12:30:00-13:12:49:00 extrusion tooling being tested TD09B, FMP886, 01:12:15:00-01:12:29:00 extrusion tool in production

SCENE 10.

TD10A, FTD06, 05:06:24:00-05:06:37:00

forging operation

TD10B, ANI: Finished Tool Cost

Tool Design~5%

Machine Time & Labor~30%

Heat Treatment~15%

Finish Machining & Labor~30%

Benchwork & Tryout~15%

TD10C, brushed steel background

SCENE 11.

TD11A, HSM06, 07:21:15:00-07:21:41:00 zoom out, high speed machining operation

SCENE 12.

TD12A, FTD30, 10:02:48:00-10:03:01:00 progressive die being worked on

TD12B, FTD28, 08:01:16:00-08:01:38:00

pan, transfer die idle

NARRATION (VO):

EVERY TROUBLESHOOTING PROJECT MUST BEGIN

WITH AN UNDERSTANDING OF THE TOOLING

INVESTMENT, SPECIFICALLY, THE

RELATIONSHIP BETWEEN THE TOOL COST AND

ITS EXPECTED PRODUCTION PERFORMANCE.

NARRATION (VO):

GENERALLY SPEAKING, TOOLING INVESTMENT

Tool Steel/Tooling Material~5% CAN BE BROKEN DOWN IN TERMS OF OVERALL

FINISHED TOOL COST AS FOLLOWS:

THE TOOL STEEL, OR TOOLING MATERIAL, AND

THE TOOL DESIGN TOTAL ABOUT 5% EACH,

THE MACHINE TIME AND LABOR TOTALS 30%,

HEAT TREATMENT, 15%,

FINISH MACHINING AND LABOR, 30%

AND BENCHWORK AND TRYOUT, 15%.

NARRATION (VO):

THE COST OF A TOOLING MATERIAL CAN BE

RELATIVELY INSIGNIFICANT WHEN COMPARED

TO THE COST OF MANUFACTURING THE

FINISHED TOOL.

NARRATION (VO):

IN TURN, THE COST OF A FINISHED TOOL

PALES IN COMPARISON TO THE HIGH COST OF

PRODUCTION DOWN TIME DUE TO UNEXPECTED

TOOL FAILURE. THESE COSTS MOST

FREQUENTLY RUN INTO THOUSANDS OF DOLLARS

AN HOUR PLUS SCRAP COSTS.

--- TOUCH BLACK ---

SCENE 13.

TD13A, FTD102, 12:34:47:00-12:35:18:00 zoom out, failed tool, loop at end if necessary

Action

### NARRATION (VO):

WHEN A TOOL OR DIE UNEXPECTEDLY OR

PREMATURELY FAILS, TROUBLESHOOTING

SHOULD BE PERFORMED USING A METHODICAL,

FOUR-STEP PROCESS:

FIRST, GATHER ALL THE FACTS,

SECOND, CONFIRM & COMPARE THE FACTS TO

BEST PRACTICES,

THIRD, SEARCH OUT THE ROOT CAUSE OR

CAUSES OF THE FAILURE,

AND FOURTH, PLAN AND TEST A CORRECTIVE

--- TOUCH BLACK ---

SCENE 14.

TD14A, CGS: Gather all the Facts TD14B, zoom out, failed tool

TD14C, CGS: Production Expectations
Manufacturing Parameters &

Procedures

Tooling Failure Type/Failure

Mode

TD14D, zoom in, failed tool

### NARRATION (VO):

ACTION.

TO BEGIN TROUBLESHOOTING, GATHER ALL THE FACTS REGARDING THE PRODUCTION

EXPECTATIONS, MANUFACTURING PARAMETERS

AND PROCEDURES, AND THE TOOLING FAILURE

TYPE, COMMONLY REFERRED TO AS THE

FAILURE MODE. THIS INITIAL PROCESS IS

FREQUENTLY THE MOST IMPORTANT AND

SOMETIMES THE MOST DIFFICULT.

## SCENE 15.

TD15A, FTD102, 12:51:34:00-12:51:59:00 zoom out, powder metal operation TD15B, FTD102, 12:36:09:00-12:36:28:00 pan, failed tool

### NARRATION (VO):

ONCE DONE, EACH CAN BE REVIEWED,

ANALYZED, AND EVALUATED IN TERMS OF ITS

AFFECT ON A TOOL'S OVERALL PERFORMANCE

AND WHETHER OR NOT IT MIGHT BE A

POSSIBLE ROOT CAUSE FACTOR OF THE

FAILURE BEING ADDRESSED.

#### SCENE 16.

TD16A, FTD95, 03:56:33:00-03:56:48:00 zoom out, die being machined TD16B, FTD97, 05:15:58:00-05:16:09:00 mold being repaired TD16C, FTD97, 05:39:14:00-05:39:29:00 mold being placed in machine

### SCENE 17.

TD17A, zoom out, failed tool
TD17B, CGS: Tool Size
Weight

Design Configuration
Thermal Geometry
Rough Machine Process
Rigors of the Production
Operation

#### SCENE 18.

TD18A, FMP898, 13:17:32:00-13:17:48:00 zoom out, extrusion tooling in operation TD18B, FTD59, 11:32:57:00-11:33:10:00 zoom in, cad operator TD18C, FTD94, 02:15:20:00-02:15:39:00 heat treater at controls TD18D, FMP667, 00:06:46:00-00:06:57:00 machinist working on tooling

### NARRATION (VO):

PRESSURE FOR A QUICK SOLUTION ALL TOO
FREQUENTLY OVERRIDES CAREFUL
TROUBLESHOOTING ANALYSIS. DO NOT ALLOW
MANUFACTURING CONSTRAINTS, PRODUCTION
SCHEDULES AND QUICK-FIX THINKING TO
OVERRIDE THOROUGH ANALYSIS AND
COMMONSENSE.

#### NARRATION (VO):

HAVING A FAILED TOOL OR DIE ON HAND FOR
EXAMINATION IS AN EXCELLENT MEANS OF
GATHERING DETAILS RELATED TO A TOOL'S
CHARACTER AND FAILURE MODE. THIS
INCLUDES INFORMATION REGARDING THE TOOL
SIZE, WEIGHT, MASS, DESIGN
CONFIGURATION, THERMAL GEOMETRY, ROUGH
MACHINE PROCESS, AND RIGORS OF THE
PRODUCTION OPERATION.

### NARRATION (VO):

ANOTHER VITAL PART OF THE FACT-FINDING
PROCESS IS TO GET PERSPECTIVES OF A
TOOL'S PERFORMANCE AND FAILURE FROM
DIFFERENT DEPARTMENTS. ENGINEERS, HEAT

TREATERS, TOOL MAKERS AND MACHINE
OPERATORS ALL VIEW TOOL PERFORMANCE FROM
A DIFFERENT PERSPECTIVE, AND MAY HAVE
UNIQUE INSIGHT INTO A TOOLING PROBLEM.

#### SCENE 19.

TD19A, checklist

TD19B, blue background TD19C, pan of checklist

TD19D, checklist page peeling onto blue background

# SCENE 20.

zoom in, people looking at blue prints
TD20B, FMP492, 21:11:53:00-21:12:16:00
hot forging operation
TD20C, FMP368, 06:13:33:00-06:14:12:00

TD20A, FTD99, 09:43:50:00-09:44:06:00

TD20C, FMP368, 06:13:33:00-06:14:12:00 zoom out, powder metallurgy operation

#### SCENE 21.

continue previous shot

TD21A, CGS: Production Processes

Production Machinery

State of Repair Clamping Pressures Tonnages Used Tool Alignment

TD21B, CGS: Tolerances

Clearances
Heat Generated
Cycle Speeds
Lubrication

### NARRATION (VO):

A CHECKLIST IS HELPFUL IN GATHERING

FACTS BECAUSE IT PROVIDES A STRUCTURED,

STEP-BY-STEP TROUBLESHOOTING APPROACH.

THE LIST ALSO PROVIDES A FIRM PLATFORM

FOR ANALYZING AND EVALUATING PROBLEMS,

AND SUMMARIZING ANY TROUBLESHOOTING

RECOMMENDATIONS.

#### NARRATION (VO):

DETAILED TOOLING SPECIFICATIONS, BLUE
PRINTS AND TOOLING IDENTIFICATION
NUMBERS ARE ALL USEFUL IN DESCRIBING THE
CONSTRUCTION PARAMETERS OF A TOOL. THESE
SPECIFICATIONS ALSO SUPPLY VALUABLE
INFORMATION REGARDING SPECIFIC TOOLING
PROCESSING DETAILS AND THEIR
VERIFICATION.

# NARRATION (VO):

PRODUCTION PROCESSES, PRODUCTION

MACHINERY, THEIR STATE OF REPAIR,

CLAMPING PRESSURES, TONNAGES USED, TOOL

ALIGNMENT, TOLERANCES, CLEARANCES, HEAT

GENERATED, CYCLE SPEEDS, AND

LUBRICATION, ARE ALL IMPORTANT FACTORS TO DOCUMENT.

SCENE 22.

TD22A, FMP484, 15:21:42:00-15:22:35:00 ring rolling operation

### NARRATION (VO):

ADDITIONALLY, THE TYPE OF PRODUCTION MATERIAL AND ITS VARIOUS PROPERTIES, SUCH AS HARDNESS, TOUGHNESS, AND ABRASIVENESS CAN ALL FACTOR INTO A TOOL'S PERFORMANCE.

SCENE 23.

TD23A, FMP508, 22:01:00:00-22:01:30:00 tooling being placed into quench tank

### NARRATION (VO):

HEAT TREATING IS A SIGNIFICANT CONTRIBUTING FACTOR TO THE SUCCESS OR FAILURE OF A TOOL, SO ITS IMPERATIVE THAT AS MUCH INFORMATION BE DETAILED CONCERNING A GIVEN TOOL'S HEAT TREATMENT.

SCENE 24.

TD24A, FTD93, 01:08:14:00-01:08:38:00 zoom out, heat treater setting up furnace

# NARRATION (VO):

OFTEN, IT IS MORE IMPORTANT TO GET THIS INFORMATION FROM THE ENGINEERS, TOOL ROOM PERSONNEL AND HEAT TREATERS THAN IT IS FROM CHARTS OR CERTIFICATIONS.

TD25A, FTD94, 02:54:05:00-02:54:49:00

tooling going into furnace TD25B, CGS: Furnace - Type Condition

Capacity

-Thermal-Couple Accuracy &

Placement

-Atmosphere Type --Batch Description

--Process Temperatures & Soak

Times

TD25C, FMP507, 21:09:37:00-21:10:02:00 parts pulled from furnace placed in quench

# NARRATION (VO):

ASK FOR SPECIFIC DETAILS REGARDING THE FURNACE, SUCH AS THE - TYPE, CONDITION, CAPACITY, -THERMAL-COUPLE ACCURACY AND PLACEMENT, -ATMOSPHERE TYPE, - -BATCH DESCRIPTION, - - PROCESS TEMPERATURES AND SOAK TIMES. FIND OUT ABOUT THE :-PREHEAT TD25D, FTD94, 02:27:12:00-02:27:28:00 zoom in, hardness testing of tool

PROCEDURES USED; - CHECK THE- HARDENING

TEMPERATURE, - SOAK TIME AT THE

HARDENING TEMPERATURE, THE -QUENCH TYPE,

RATE AND UNIFORMITY. ALSO CHECK IF THE,

DURATION-AS-QUENCHED HARDNESS WAS IF

TAKENMEASURED, -TEMPERING- AS WELL AS THE

TYPE OF HOW MANY TEMPERS- TEMPERING

TEMP., SOAK TIMES AT TEMP., COOLING

PROCESS BETWEEN TEMPERS. AND THE 
RESULTING HARDNESS.

--- TOUCH BLACK ---

SCENE 26.

TD26A, CGS: Confirm & Compare the Facts to Best Practices

TD26B, FTD11, 10:04:36:00-10:04:54:00 zoom out, milling of injection mold tooling

TD26C, FMP667, 00:19:40:00-00:20:00:00 zoom out, milling of stamping tooling

SCENE 27.

TD27A, FTD102, 12:20:59:00-12:21:11:00 zoom out, failed powder metal tool TD27B, FMP366, 04:05:30:00-04:05:50:00 zoom out, powder metal operation TD27C, FTD102, 12:52:42:00-12:52:59:00 zoom out, powder metal operation

# NARRATION (VO):

AT THIS POINT, ITS IMPORTANT TO CONFIRM

AND COMPARE THE TOOLING CONSTRUCTION

DETAILS TO BEST PRACTICES TO DETERMINE

IF THEY WERE FOLLOWED IN PRODUCTION.. IT

ALSO HELPS FACILITATES THE

TROUBLESHOOTING PROCESS AS IT ALLOWS FOR

AN INDEPENDENT EYE TO REVIEW AND CONFIRM

MANY OF THE DETAILS PREVIOUSLY GATHERED.

# NARRATION (VO):

THE 'ROOT CAUSE' FAILURE MODE SHOULD BE

EXAMINE THE FAILED TOOL NOT THE PRINT OR

DRAWING THE FIRST STEP IN THIS PROCESS

IS TO BECOME FAMILIAR WITH THE FAILED

TOOL IN QUESTION. THE OLD ADAGE "SEEING

IS BELIEVING," PLAYS TRUE WHEN IT COMES

TO EXAMINING THE ACTUAL FAILED TOOL.

THIS IS INTEGRAL TO THE TROUBLESHOOTING PROCESS. IT SERVES MANY PURPOSES AS IT CAN: A. FAMILIARIZES THE TROUBLESHOOTER WITH THE SCOPE OF THE ACTUAL TOOL IN QUESTION. TERMS OF MACHINING TO DIMENSION AND TOLERANCE, HEAT TREATING, FINISH MACHINING, ECCIDENTIFIED AND CONFIRMED, AND CHECKED TO SEE HOW IT RELATES TO THE TOOLING DESIGN CONFIGURATION, ACTUAL HARDNESS AND PRODUCTION OPERATION.

SCENE 28.

TD28A, FTD101, 11:32:23:00-11:32:53:00
zoom in, hardness testing of forging tool
TD28B, FMP503, 15:25:26:00-15:25:37:00
hardness testing of material

### NARRATION (VO):

A. TOOL STEELS DIFFER WIDELY GRADE TO

GRADE IN THEIR CHARACTERISTICS,

ENGINEERING PROPERTIES AND HEAT

TREATMENT. FOR THIS REASON, ITS

IMPORTANT 2.IDENTIFY THE GRADE OF

MATERIAL TO DETERMINE WITH ANY DOUBT THE

GRADE OF THE TOOL MATERIAL IN QUESTION.

OFTEN IT IS BEST TO DOUBLE CHECK THE

GRADE EVEN IF YOU NEED TO HAVE IT TESTED

METALLURGICALLY.

SCENE 29.

TD29A, FTD103, 13:16:38:00-13:17:07:00 zoom in, hardness testing of failed tool

#### NARRATION (VO):

3.CONFIRM THE HARDNESS TESTING HARDENING
PROCEDURE IN DETAIL CAREFUL HARDNESS
TESTING CAN CONFIRM THIS INFORMATION. A.
TAKE A MINIMUM OF FOUR READINGS IN AT

LEAST THREE DIFFERENT SECTIONS OF THE

TOOL. B. IT'S GOODGOD PRACTICE TO MAKE

THESE HARDNESS TESTS IN BOTH THE WORKING

AREAS AND NON-WORKING AREAS OF THE

TOOL.IN QUESTION'S. DOCUMENT YOUR

FINDINGS FOR FUTURE REFERENCE.

SCENE 30.

TD30A, FTD102, 12:16:51:00-12:17:03:00 zoom out, failed tool, freeze frame after zoom

TD30B, freeze frame of failed tool

TD30C, CGS: Are there any rough machining marks on the tool?

TD30D, CGS: What is its the depth of the failure zone?

TD30E, CGS: Where is the nucleation point and how did it propagate?

TD30F, CGS: Did the failure zone initiate from or propagate to a stress raiser?..

#### NARRATION (VO):

4.A. BE COMPREHENSIVE. INSPECT THE WHOLE TOOL, NOT JUST THE FAILURE AREA. SEEK ANSWERS TO THE FOLLOWING QUESTIONS:

ARE THERE ANY ROUGH MACHINING MARKS ON THE TOOL?

WHAT IS ITS THE DEPTH OF THE FAILURE ZONE?

WHERE IS THE NUCLEATION POINT AND HOW DID IT PROPAGATE?

AND DID THE FAILURE ZONE INITIATE FROM
OR PROPAGATE TO A STRESS RAISER?.. KEEP
A SHARP EYE OUT FOR STRESS RAISERS AND
THE ROLE THEY MIGHT HAVE PLAYED IN
INITIATING THE FAILURE BEING ADDRESSED.

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SCENE 31.

TD31A, still, failed tool TD31B, still, failed tool TD31C, still, failed tool

## NARRATION (VO):

ALSO, CHECK FOR CRACKS IN OTHER AREAS OF
THE TOOL. LOOK SPECIFICALLY FOR TINY
TIGHT CRACKS AROUND STRESS RAISERS LIKE
HOLES, SHARP CORNERS OR EDGES, TIGHT
RADIUSES, SECTION CHANGES, AND KEY SLOTS

AND SHARP EDGES. CRACKS IN THESE AREAS MIGHT BE EVIDENCE OF AGGRESSIVE, SUBSTANDARD GRINDING.

SCENE 32.

TD32A, FTD102, 12:22:59:00-12:23:14:00 zoom in, failed powder metal tool

#### NARRATION (VO):

5.NOTE ALL OF THE ANOMALIES IN THE END,
THIS INSPECTION SHOULD REVEAL IF A
FAILED WASWASTOOL WAS CONSTRUCTED
ACCORDING TO PROPER SPECIFICATIONS AND
BEST PRACTICES.

--- TOUCH BLACK ---

SCENE 33.

TD33A, CGS: Searching out the Root

Cause or Causes

TD33B, CGS: Planning & Testing a

Corrective Action

TD33C, FTD102, 13:02:16:00-13:02:40:00

pan, defective tools on table

#### NARRATION (VO):

SEARCHING OUT THE ROOT CAUSE OR CAUSES

OF A FAILURE AND PLANNING AND TESTING A

CORRECTIVE ACTION THIS ARE THE FINAL TWO

STEPS IN THE TROUBLESHOOTING PROCESS.

ACCOMPLISHING THESE STEPS SUCCESSFULLY

IS DEPENDENT UPON HOW WELL AND

ACCURATELY THE PREVIOUS STEPSTWO WERE

CARRIED OUT.

# SCENE 34.

TD34A, FMP364, 01:07:55:00-01:08:12:00 zoom out, repressing of powder parts TD34B, FTD85, 15:12:19:00-15:12:32:00 zoom in, edming of tool TD34C, FMP896, 12:06:13:00-12:06:30:00 zoom out, cold extrusion of part

#### NARRATION (VO):

THE FAILURE MODES AND TRIGGER

MECHANISMS, STRESSES THAT INITIATE AND

FACILITATE TOOL FAILURE CAN COME FROM

MANY SOURCES. THE KEY TO SUCCESSFUL TOOL

AND DIE TROUBLESHOOTING IS TO IDENTIFY,

AND MINIMIZE AND/OR ELIMINATE THE

STRESSES THAT TRIGGER FAILURE.

SCENE 35.

TD35A, zoom in, still, failed tool
TD35B, MND06, 06:04:55:00-06:05:05:00
tool test material failing
TD35C, MND15, 15:53:40:00-15:53:52:00
tool test material failing

SCENE 36.

TD36A, HSM06, 07:19:42:00-07:20:36:00
zoom out, machining operation
TD36B, CGS: Mechanical Stresses
Thermal Stresses
Transformation Stresses

### NARRATION (VO):

ALL TOOLING, REGARDLESS OF HOW IT WAS DESIGNED, THE GRADE OF STEEL IT IS MADE FROM, HOW IT WAS MACHINED, HEAT TREATED OR USED AND BUILT, WILL FAIL IF IT IS STRESSED BEYOND ITS 'ULTIMATE TENSILE STRENGTH'. ADDITIONALLY, A TOOL'S ULTIMATE TENSILE STRENGTH OF A GIVEN TOOL IS REDUCED AS STRESSES INCREASE.

## NARRATION (VO):

THERE ARE THREE PROMINENT AND BASIC

TYPES OF TENSILE STRESSES THAT WORK IN

COMBINATION TO REDUCE A TOOL'S ULTIMATE

TENSILE STRENGTH: GIVEN PIECE OF ING

MECHANICAL STRESSES,

THERMAL STRESSES,

AND TRANSFORMATION STRESSES.

--- TOUCH BLACK ---

SCENE 37.

TD37A, CGS: Mechanical Stresses TD37B, FTD16, 16:10:31:00-16:10:51:00 zoom out, turning of large roll

### NARRATION (VO):

MECHANICAL STRESSES DEVELOP FROM THE

VARIOUS MACHINING PROCESSES USED TO

REMOVE UNWANTED MATERIAL FROM A

WORKPIECE WHILE GENERATING A TOOL OR

DIE.

## SCENE 38.

TD38A, FMP667, 00:04:08:00-00:04:54:00 zoom out, rough machining TD38B, HSM06, 07:16:54:00-07:17:21:00 zoom in, high speed machining

### NARRATION (VO):

-ROUGH MACHINE MARKS ROUGH MACHINING
PRODUCES BUILT-IN SURFACE NOTCHES AND

SHARP CORNERS THAT CONCENTRATE STRESSES.

ALL TOO FREQUENTLY, ROUGH MACHINING

MARKS BECOME NUCLEATION SITES FOR CRACK

PROPAGATION IN HEAT TREATING AND IN

SERVICE OPERATION.

SCENE 39.

TD39A, FMP963, 11:03:46:00-11:04:27:00 pan, stamp marks used to identify roll forming rolls

TD39B, still, crack at stamp mark on tool

#### NARRATION (VO):

STAMP MARKS USED TO IDENTIFY TOOLING CAN
BE THE NUCLEATION SITE FOR STRESS

CONCENTRATION IN THIS LIGHT, THEY

CANAND CAN THE TRIGGER MECHANISM FOR

TOOL DISTORTION AND MICRO-CRACKING.

THESE STRESSES CAN ALSO WORK IN

COMBINATION WITH OTHERS TO CAUSE FATIGUE

FAILURES.

--- TOUCH BLACK ---

SCENE 40.

TD40A, CGS: Thermal Stresses

TD40B, FMP492, 21:04:56:00-21:05:15:00

hot forging operation

TD40C, FMP492, 21:16:00:00-21:16:20:00

hot forging operation

## NARRATION (VO):

-THERMAL STRESSES: HEATING AND COOLING
FORM FROM VARIOUS MACHINING, HEAT
TREATING AND PRODUCTION OPERATIONS CAUSE
THE SURFACE OF A GIVEN TOOL TO TOOL TO
EXPAND AND SUBSEQUENTLY TO CONTRACT.
THIS ACTION IMPARTS TENSILE STRESSES TO
THE TOOL AS IT BEING HEATSED ORAND
COOLEDCOOLSHEATED AND COOLED.

SCENE 41.

TD41A, FMP481, 13:16:54:00-13:17:26:00

hot forging operation

TD41B, FMP450, 17:25:51:00-17:26:18:00

zoom in, die casting operation

### NARRATION (VO):

THESE THERMAL STRESSES BECOME MORE
SEVERE AS THE EXPANSION AND CONTRACTION

IS REPEATED UNDER RAPID THERMAL CYCLING.

AS AREAS OF THE TOOL THAT DO NOT BECOME

HOT AND COLDCHANGE TEMPERATURE RESIST

THE EXPANSION AND CONTRACTION, THE

STRESSES IMPARTED BECOME COMPOUNDED.

THIS IS CALLED HOT UPSETTING.

SCENE 42.

continue previous shot

TD42A, zoom out, still, micro cracks from thermal stress

### NARRATION (VO):

THERMAL STRESSES CAN LEAD TO TOOL

DISTORTION, MICRO-CRACKING, SURFACE

TEMPER SOFTENING, AND WORK AND IN

COMBINATION WITH OTHER STRESSES TO

FACILITATE THE DEVELOPMENT OF FATIGUE

FAILURES.

--- TOUCH BLACK ---

SCENE 43.

TD43A, CGS: Transformation Stresses TD43B, FMP507, 21:06:47:00-21:07:02:00

parts dipped in salt bath in martempering operation

TD43C, ANI: glowing body-centered cubic crystalline structure rotating, dissolve into next image

TD43D, ANI: glowing densely packed, face-centered cubic crystalline structure rotating

#### NARRATION (VO):

-TRANSFORMATION STRESSES: WHEN ANNEALED STEEL IS HEATED TO TEMPERATURES ABOVE APPROXIMATELY 1300° FAHRENHEIT, OR 704° CELSIUS, THE STEEL TRANSFORMS TO A STRUCTURE CALLED AUSTENITE. WHEN THIS HAPPENS, THE BODY-CENTERED CUBIC ATOMS, WHICH MAKE UP THE CRYSTALLINE STRUCTURE OR LATTICE, REARRANGE THEMSELVES, TRANSFORMING INTO A MORE DENSELY PACKED, FACE-CENTERED CUBIC CRYSTALLINE STRUCTURE. THE STEEL SHRINKS AND BECOMES NON-MAGNETIC.

SCENE 44.

TD44A, FTD103, 13:06:07:00-13:06:22:00 parts put into salt bath quench TD44B, still, photomicrograph of martensite

TD44C, still, photomicrograph of martensite

TD44D, ANI: glowing densely packed, face-centered cubic crystalline structure rotating, dissolve into next image TD44E, ANI: quenched less dense body-centered cubic tetragonal crystalline structure rotating

TD44F, still, photomicrograph of stress cracked martensite

TD44G, still, photomicrograph of stress cracked martensite

SCENE 45.

TD45A, FTD98, 07:01:18:00-07:01:41:00 zoom in, edming progressive die TD45B, FTD36, 16:02:30:00-16:02:56:00 progressive die operation TD45C, FTD98, 07:15:00:00-07:15:14:00 broken progressive die tooling

# NARRATION (VO):

WHEN THIS STEEL IS RAPIDLY QUENCHED TO A
LOW TEMPERATURE FROM ITS AUSTENITIC

TEMPERATURE RANGE, THE AUSTENITE

TRANSFORMS TO MARTENSITE. THIS NEWLY

FORMED, UNTEMPERED MARTENSITE IS

UNSTABLE, AND AS IT BEGINS TO DEVELOP,

THE STEEL'S CRYSTALLINE STRUCTURE

TRANSFORMS FROM THE DENSELY PACKED,

FACE-CENTERED CUBIC STRUCTURE TO A LESS

DENSE, BODY-CENTERED CUBIC TETRAGONAL

CRYSTALLINE STRUCTURE. THIS CAUSES THE

STEEL TO GROW, CREATING STRESSES AND

HARDENING IT. THE STEEL ALSO REGAINS ITS

MAGNETIC PROPERTIES.

### NARRATION (VO):

IT HAS TO BE UNDERSTOOD THAT THE

RESIDUAL MECHANICAL STRESSES FROM

MACHINING CAN WORK IN COMBINATION WITH

RESIDUAL THERMAL AND TRANSFORMATION

STRESSES IMPARTED FROM HARDENING AND

TEMPERING DURING HEAT TREATING. THESE

STRESSES IN TURN CAN GROW IN FORCE AND

MAGNITUDE TO EQUAL OR EXCEED A TOOL'S

ULTIMATE TENSILE STRENGTH. WHEN THIS

HAPPENS, THE TOOL WILL FAIL.

--- TOUCH BLACK --- (GRINDING, WELDING,

EDM, ETC.).

SCENE 46.

TD46A, FMP906, 01:02:40:00-01:03:17:00

edming of tooling

TD46B, CM47, 19:24:30:00-19:25:00:00

tooling being machined
TD46C, CGS: Tool Design

Tool Steel Selection Hardening & Tempering Rough & Finish Machining

SCENE 47.

TD47A, CGS: Tool Design

TD47B, FTD71, 05:25:59:00-05:26:21:00
zoom out, cad drawing being worked on
TD47C, FTD80, 10:29:14:00-10:29:55:00
zoom out, linear static study showing
strain too high at point in 3D model, zoom
in, model modified to eliminate strain
TD47D, FTD31, 08:27:08:00-08:27:35:00
zoom in, cad drawing of tooling being

worked on

TD47E, CGS: Massive Cross Sections
Sharp Internal Corners
Significant Section Changes

Blind Holes

Thin Wall Sections Delicate Protrusions

Unbalanced Configurationsand/

Intricate Designs

NARRATION (VO):

DURING A TOOL'S DEVELOPMENT AND

CONSTRUCTION, SOME OF THE PRIMARY AREAS

WHERE STRESSES CAN APPEAR AND BE

MANAGED, MINIMIZED AND CONTROLLED

INCLUDE:

THE TOOL DESIGN,

THE TOOL STEEL SELECTION,

IN THE HARDENING AND TEMPERING

PROCESSES,

AND DURING ROUGH- AND FINISH MACHINING

OPERATIONS.

NARRATION (VO):

TOOL DESIGN MUST BE A PROACTIVE, RATHER

THAN A REACTIVE, PROCESS. AS DESIGN

ENGINEERS BEGIN TO DEVELOP A GIVEN TOOL

FOR PRODUCTION, THEY MUST WORK TO: A.

MINIMIZE FACTORS THAT ACT AS STRESS

RAISERS. DESIGNERS SHOULD GIVE SPECIAL

CONSIDERATION TO TOOLS HAVING MASSIVE

CROSS SECTIONS, SHARP INTERNAL CORNERS,

SIGNIFICANT SECTION CHANGES, BLIND

HOLES, THIN WALL SECTIONS, DELICATE

PROTRUSIONS, UNBALANCED CONFIGURATIONS,

AND/OR INTRICATE DESIGNS.

SCENE 48.

TD48A, FTD103, 13:11:38:00-13:11:54:00 zoom out, parts in heat treat furnace

NARRATION (VO):

TD48B, FTD103, 13:09:13:00-13:09:27:00 zoom in, bar being tempered

THIS IS ESPECIALLY TRUE WHEN IT PERTAINS

TO HEAT TREATMENT. AVOID SPECIFYING

EXCESSIVELY HIGH HARDNESS LEVELS.

INSTEAD, SELECT A RANGE OF HARDNESS THAT

ALLOWS S THE TOOL TO BE THOROUGHLY

TEMPERED AFTER HARDENING AND QUENCHING.

SCENE 49.

TD49A, CGS: Tool Steel
TD49B, CM47, 19:13:27:00-19:13:56:00
zoom out, tool steel being machined

NARRATION (VO):

WHEN SELECTING A TOOL STEEL, CHOOSE AN AIR-HARDENING STEEL WHENEVER POSSIBLE.

AIR-HARDENING STEELS CAN BE HARDENED WITH SIGNIFICANTLY LOWER STRESS DEVELOPMENT AND BETTER DIMENSIONAL STABILITY THAN MOST OTHER TOOL STEELS.

SCENE 50.

TD50A, FTD06, 05:17:09:00-05:17:37:00 zoom out, forging operation

NARRATION (VO):

BALANCE THE WEAR RESISTANCE OF THE TOOL

STEEL AGAINST THE NEED FOR TOUGHNESS AND

IMPACT STRENGTH. LOWER CARBON STEELS ARE

USUALLY TOUGHER AND MORE DUCTILE THAN

HIGHER CARBON STEELS, WHICH HAVE HIGHER

ABRASION RESISTANCE, BUT ARE MORE

BRITTLE.

SCENE 51.

TD51A, FTD09, 08:42:02:00-08:42:20:00 zoom out, hot rolling at mill TD51B, ANI: barstock, longitudinal grain direction highlighted along length TD51C, CGS: Longitudinal Grain Direction

# NARRATION (VO):

CONVENTIONAL TOOLING STEELS HAVE A

NATURAL GRAIN DIRECTION. THIS IS THE

DIRECTION IN WHICH THE STEEL WAS

ELONGATED DURING FORGING AND ROLLING AT

THE MILL AND IT IS REFERRED TO AS THE

LONGITUDINAL GRAIN DIRECTION.

SCENE 52.

TD52A, ANI: barstock, force applied perpendicular to the longitudinal grain direction

TD52B, FMP293, 02:01:28:00-02:01:43:00 stamping operation

TD52C, FMP895, 10:18:53:00-10:19:20:00 zoom out, cold extrusion operation TD52D, FTD14, 13:28:46:00-13:29:07:00 zoom in, powder metallurgy operation

SCENE 53.

TD53A, CGS: Hardening & Tempering
TD53B, FTD83, 13:43:12:00-13:43:32:00
batch processing of tooling pulled from furnace

TD53C, FTD83, 13:44:16:00-13:44:26:00 batch tooling placed under cooling fans TD54A, FTD83, 13:47:38:00-13:48:06:00 batch tooling cooling

SCENE 54.

continue previous shot

TD54B, CGS: Dimensional Stability

Compressive Strength

Impact Strength

Toughness

Abrasive Wear Resistance

TD54C, CGS: Adhesive Wear

Seizing
Galling
Deformation
Temper Softening

### NARRATION (VO):

STEEL IS MUCH STRONGER AND MORE
RESISTANT TO BREAKAGE WHEN THE FORCES OF
PRODUCTION ARE PERPENDICULAR, OR
TRANSVERSE, TO THE LONGITUDINAL GRAIN
DIRECTION OF A TOOL. THE TOOL DESIGN
ENGINEER OR TOOL MAKER SHOULD STRIVE TO
ORIENT THE GRAIN DIRECTION OF THE
TOOLING MATERIAL FOR MAXIMUM STRENGTH.

#### NARRATION (VO):

THE GOAL OF HARDENING AND TEMPERING A

TOOL IS TO DEVELOP A DESIRED SET OR

COMBINATION OF ENGINEERED MECHANICAL

PROPERTIES. THESE PROPERTIES WILL VARY

DEPENDENT UPON THE SPECIFICS OF THE

PRODUCTION OPERATION, TOOL DESIGN AND

CONFIGURATION.

## NARRATION (VO):

PROPERTIES SUCH AS DIMENSIONAL

STABILITY, COMPRESSIVE STRENGTH, IMPACT

STRENGTH, TOUGHNESS, ABRASIVE WEAR

RESISTANCE, ADHESIVE WEAR, SEIZING,

GALLING, DEFORMATION AND TEMPER

SOFTENING MUST BE DEVELOPED, PRESERVED,

OR FINE TUNED WITHIN THE HARDENING

OPERATION.

SCENE 55.

TD55A, zoom out, decarburized punch TD55B, zoom out, photomicrograph of decarburized steel

TD55C, FTD93, 01:34:42:00-01:34:54:00 zoom in, heat treated tools

SCENE 56.

TD56A, FTD93, 01:42:55:00-01:43:04:00 zoom out, batch load with detailed hardening specifications

SCENE 57.

TD57A, FTD94, 02:38:49:00-02:39:10:00 batch tooling placed in furnace TD57B, FTD93, 01:32:49:00-01:33:02:00 tooling being pulled from furnace TD57C, FTD94, 02:33:55:00-02:34:14:00 multiple tools being fixtured for heat treating

SCENE 58.

TD58A, FTD83, 13:02:06:00-13:02:42:00 zoom out, hardness testing of tool

#### NARRATION (VO):

AVOID HEAT TREATMENT PROCESSING THAT CAN DEVELOP SURFACE DECARBURIZATION, A CONDITION THAT PRODUCES A SOFT SURFACE LAYER, WHICH IS HIGHLY STRESSED. EITHER PURCHASE DECARB-FREE STEELS OR MACHINE WELL BELOW ANY DECARB ALLOWANCES ON ALL SIX SIDES OF THE WORKPIECE.

#### NARRATION (VO):

B. HEAT TREATING SPECIFICATIONS-ALWAYS
GIVE YOUR HEAT TREATER SPECIFIC AND
DETAILED HARDENING SPECIFICATIONS.

### NARRATION (VO):

DISCUSS WITH YOUR HEAT TREATER HOW YOUR TOOLING WILL BE PROCESSED IN TERMS OF HARDENING TEMPERATURES, SOAK TIMES AND BATCH PROCESSING. WHILE THERE MIGHT BE CONSIDERABLE LATITUDE WITH REGARD TO THESE PROCESSES, BE SURE THAT THEY FIT WITHIN YOUR OPTIMUM TOOLING PARAMETERS. AVOID AND/OR CONTROL BATCH PROCESSING THAT FAVORS OTHER TOOLING MATERIALS BEING PROCESSED WITH YOUR TOOLING.

### NARRATION (VO):

HAVE YOUR HEAT TREATER CHECK AND RECORD

THE AS-QUENCHED HARDNESS OF YOUR TOOLING

WHENEVER POSSIBLE. THIS WILL GIVE YOU AN

INDICATION OF HOW WELL THE TOOL REACTED

TO THE HARDENING PROCESS. THE AS-QUENCH

HARDNESS ALSO CAN BE USED AS A BENCHMARK

FOR OPTIMIZING SUBSEQUENT TEMPERING

OPERATIONS.

SCENE 59.

TD59A, FTD103, 13:15:48:00-13:16:04:00 tooling pulled from tempering furnace

SCENE 60.

TD60A, FMP503, 15:13:25:00-15:13:55:00 tooling placed in tempering furnace TD60B, FTD103, 13:12:33:00-13:12:55:00 zoom out, tool that has been tempered TD60C, FTD103, 13:11:03:00-13:11:21:00 pan, tempering furnaces

#### NARRATION (VO):

D. TEMPERING AFTER QUENCHING REMEMBER,

TEMPERING IS THE FOCAL POINT OF THE

HARDENING OPERATION. TEMPERING IT FINE

TUNES, PROTECTS, BALANCES AND PRESERVES

THE ENGINEERING PROPERTIES THAT ARE

NEEDED FOR GOOD TOOL LIFE AND

PERFORMANCE. -HAVE ALL TOOLING DOUBLE

TEMPERED.

#### NARRATION (VO):

IT IS BEST TOHAVE ALL TOOLING TEMPERED

AT THE HIGHEST TEMPERING TEMPERATURE

COMMENSURATE WITH THE DESIRED HARDNESS

OF THE TOOL. DOUBLE TEMPERING IS A

SAFEGUARD THAT HELPS TO PROMOTE MORE

COMPLETE AND THOROUGH STRESS RELIEF AND

TRANSFORMATION, AND DIMENSIONAL

STABILITY. TEMPERING, AS WITH ANY HEAT

TREATING METHOD, REQUIRES MANY HOURS FOR

QUALITY PROCESSING, AND SHOULD NEVER BE

SHORT CYCLED.DOUBLE TEMPER ALL TOOLING

AFTER HARDENING AND QUENCHING-SOAK IN

THE TEMPERING FURNACE FOR A MINIMUM OF

TWO HOURS PER INCH OF GREATEST THICKNESS AT HEAT.-COOL TO ROOM TEMPERATURE AFTER THE FIRST TEMPER.-SUBSEQUENT TEMPERING CYCLES SHOULD BE DONE AT A TEMPERATURE RANGE OF 25° F LOWER THAN THE ONE PROCEEDING IT .-

#### SCENE 61.

TD61A, CGS: Rough & Finish Machining TD61B, FMP963, 11:06:00:00-11:06:15:00 zoom out, turning of roll forming tool TD61C, FTD104, 14:05:58:00-14:06:40:00 parts placed into stress relief heat treating operation TD61D, FTD104, 14:11:50:00-14:12:36:00

parts pulled from stress relief heat treating operation

#### SCENE 62.

TD62C, FTD95, 03:47:09:00-03:47:26:00 zoom in, grinding tooling TD62A, FTD02, 02:45:10:00-02:45:36:00 zoom out, edming progressive die

#### NARRATION (VO):

STRESS IS USUALLY NOT A SERIOUS TROUBLESHOOTING FACTOR BEFORE A TOOL IS HARDENED, UNLESS DISTORTION IN HEAT TREATMENT IS A CRITICAL ISSUE. STRESS RELIEF CYCLES ARE THE BEST WAY TO PROTECT TIGHT MACHINING TOLERANCES FROM DISTORTION DURING HEART TREATMENT. (BENDING, BOWING AND TWISTING FROM STRESS DEVELOPMENT) IN SOME CASES, A TWO-PHASE STRESS RELIEF CYCLE CAN BE EMPLOYED. THE FIRST STRESS RELIEF IS DONE AFTER ROUGH MACHINING; THE SECOND AFTER A SUBSEQUENT LIGHTER MACHINING TO MORE CLOSE TOLERANCES.

### NARRATION (VO):

B. FINISH MACHINING AFTER HEAT TREAT GRINDING, EDM (CONVENTIONAL AND WIRE) AND WELDING PERFORMED AFTER HARDENING AND TEMPERING OPERATIONS ARE CRITICAL MACHINING PROCESSES STEPS IN TERMS OF IMPARTING STRESSES TO TOOLING. BECAUSE

THEY ADD STRESS TO THE TOOL IN THE FORM

OF A 'HEAT AFFECTED ZONE'. THEY OF THESE

OPERATIONS SHOULD BE THOUGHT OF AS HEAT

TREAT OPERATIONS.

SCENE 63.

TD62B, FMP913, 08:22:01:00-08:22:14:00 welding of mold

TD63A, zoom in, still of welding heat affected zone

TD63B, CGS: Altering the Surface Hardness
Altering the Surface Chemistry
Altering the Metallurgy
Introducing Mechanical,
Thermal & Transformation
Stresses

SCENE 64.

TD64A, FTD29, 09:30:22:00-09:30:41:00 zoom out, progressive die operation TD64B, still, zoom in, shattered punch

### NARRATION (VO):

THIS HEAT AFFECTED ZONE IS CREATED BY
THE HEAT GENERATED DURING OPERATIONS
FINISHING. THIS ZONE MAY DAMAGE THE
WORKPIECE BY ALTERING THE SURFACE
HARDNESS, SURFACE CHEMISTRY, METALLURGY
AND MOST CRITICALLY BY INTRODUCING
MECHANICAL, THERMAL AND TRANSFORMATION
STRESSES IN THE WORKPIECE.

#### NARRATION (VO):

THE END RESULT IS A WEAKENED TOOL THAT

IS MORE SUSCEPTIBLE TO PREMATURE WEAR,

DEFORMATION AND FATIGUE CRACKING - ALL

OF WHICH MAY BECOME TRIGGER MECHANISMS

FOR TOOL FAILURE.

--- TOUCH BLACK ---

#### SCENE 65.

FTD CXM, credit music
TD65A, zoom out, still, failed roll
forming tool

TD65B, zoom in, still, failed roll form tool

TD65C, FMP962, 10:11:28:00-10:11:53:00 zoom out, machining of roll

TD65D, FMP967, 15:09:10:00-15:09:28:00 zoom out, roll forming operation

#### NARRATION (VO):

TROUBLESHOOTING TOOL AND DIE MAKING
REQUIRES ANALYZING ALL AREAS OF
POTENTIAL AND REAL STRESS DEVELOPMENT IN
A FAILED TOOL. THE GOAL IS TO REDUCE
AND/OR ELIMINATE AS MUCH OF THE RESIDUAL
STRESSES AS POSSIBLE FROM A TOOL'S

CONSTRUCTION, HEAT TREATING, FINISH

MACHINING AND PRODUCTION PROCESSES. ONCE

DONE, BEST PRACTICES MUST BE DETERMINED,

IMPLEMENTED AND STRICTLY ADHERED TO FOR

TOOLING IMPROVEMENT.

--- FADE TO BLACK ---

SCENE 66.
continue music, up and under
TD CRX, CGS, ROLL: credits
white text, fade up mid-screen
FTD EXM, extended motion background

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SCENE 67.
continue motion background
FTD DIS, CGS: disclaimer
white text, centered on background

Some machinery in this program had safety equipment removed to allow better recording of certain processes.

Always read the safety information provided in the manufacturers' manual before machine operation.

SCENE 68. FTD03A, SME logo open, with music