TIE ROD END DESIGN TUTORIAL

• THE FOLLOWING IS A SIMPLIFIED STEP-BY-STEP GUIDE INTENDED TO ILLUSTRATE THE DECISIONS AND COMPROMISES INVOLVED IN DESIGNING A TIE ROD END.

• THE PROCESS FOR DESIGNING ANY BALL JOINT IS VERY SIMILAR
DESIGNING A ROD END FOR THE 20XX HYPOTHETICAL LIGHT TRUCK

• FROM THE CUSTOMER WE LEARN:
  – 1) PT 12 RELATIVE TO KNUCKLE 26.4MM
  – 2) LOADS 7000 MAX, 4000 WORKING
  – 3) PACKAGE NO ISSUES, 30MM FROM BRAKE ROTOR DUST SHIELD
  – 4) ARTICULATION TRAVEL +/- 18 DEGREES
  – 5) MATING PARTS DETAIL CAST IRON 27MM THICK, STUD UP, CASTLE NUT/COTTERPIN
  – 6) APPLICATION COMMERCIAL LIGHT TRUCK, R&P W/ M16X 1.5 ROD
  – 7) GREASABLE / NON-GREASABLE GREASABLE
BALL STUD DESIGN INPUTS

BALL CENTER

CAST IRON

27.0 MM THICK

BOSS SURFACE TO BALL CENTER 26.4MM

INPUT LOAD

7000 LB. MAX
4000 LB WORKING
BALL STUD SHANK SIZING

- 7000 LB MAX LOAD
- 4000 LB WORKING LOAD
- 26.4MM CANTILEVER BEAM
- SHEAR-MOMENT CALCULATION
- 25% F.S.
- EFFECTIVE MATL ULT = 242KSI
- EFFECTIVE MATL YIELD = 129KSI
- => SHANK DIA = 19.6MM
TAPER SPECIFICATION

- **STEEL BOSS**
  - 1:8 TAPER
  - 1.25:1 THICK/DIA

- **CAST IRON, ALUMINUM**
  - 1:6 TAPER
  - 1.3-1.5 THICK/DIA

- **PULL UP**
  - STEEL => .4-.7MM
  - CAST IRON => .4-.7MM
  - ALUMINUM => 1.0MM

- Threads below surface with pullup.
- 3 threads showing when nut tight.
- Cotter pin location determined by castle nut.
- 1:6 taper for cast iron.
- Boss hoop stress.
CONE WASHER VS. TAPERED BALL STUD

• CONE ADVANTAGES
  – EASY SERVICE REMOVAL
  – SEAL SURFACE CONTROLLED
  – CHANGE GAGE LENGTH EASILY
    • GT ADJUSTABLE

• TAPER ADVANTAGES
  – LOCKING TAPER
  – CARBONITRIDE H.T.
  – LOWER COST
  – LESS SENSITIVE TO NUT TORQUE
BALL SIZING

• LARGER DIA
  – IMPROVES PULL OUT STRENGTH
  – REDUCES BEARING/LUBE PRESSURE
  – NO ARTICULATION UNDERCUT

• SMALLER DIA
  – MORE ROOM FOR SEAL
  – BETTER PACKAGE
  – LESS EXPENSIVE
NOW IT GETS COMPLICATED

• BETWEEN THE TOP OF THE BALL AND THE KNUCKLE WE NEED TO PACKAGE:
  – BEARING
  – FORGING
  – SEAL

• AND, IT HAS TO ARTICULATE
STEEL BEARING PACKAGE
FOR A 26MM BALL

• STANDARD HARDENED STEEL BEARING FOR 26MM BALL
• EXCELLENT WEAR CHARACTERISTICS
• EXCELLENT PULL OUT STRENGTH
• HIGHER ROTATING TORQUES
UPPER FORGING PACKAGE FOR A 26MM BALL WITH STEEL BEARING

- FORGING CONSIDERATIONS:
- 5.0MM MIN TOP THICKNESS
- HOLLOWMILL FOR SEAL RETAINER
- ARTICULATION WINDOW
DON’T FORGET ARTICULATION

• SPECIFIED 18 DEGREE ARTICULATION ANGLE DRIVES:
  – SEAL DESIGN REQUIREMENTS
  – FORGING WINDOW
WHAT HAPPENS IF WE GO TO A 30MM BALL DIAMETER?
UPPER FORGING PACKAGE FOR 30MM BALL VS. 26MM BALL
ARTICULATION STUDY
30MM VS 26MM BALL

30MM

26MM

SEAL MIN HEIGHT

SEAL MAX HEIGHT

2 DEGREES OVERTRAVEL

NEED TO OPEN ARTICULATION WINDOW
TO AVOID PINCHING THE SEAL, WE’LL USE A 26MM BALL
(BESIDES, IT’S CHEAPER)
READDRESS ARTICULATION WITH 26MM BALL

• 2 ISSUES
  – SHANK-FORGING CRASH OPEN WINDOW
  – SHANK-BEARING LINE-TO-LINE @ 2 DEGREE OVERTRAVEL LOW RISK
• COULD UNDERCUT STUD - ADDED $$$
PULL OUT STRENGTH ANALYSIS

- STUD ARTICULATED 20 DEGREES DEFINES WINDOW SURFACE A-B
- FORGING OVERLAP = .199 SQ. IN
- PULL OUT FORCE = \( \sin(18\text{DEG}) \times 1.25 \times 7000 \text{ LB} = 2704 \text{LB} \).
- RESISTING CROSS SECTION = .199 SQ. IN.
- PULL OUT STRESS = 2704 LB/0.199 SQ. IN = 13587 PSI
- MATERIAL YIELD > 30000 PSI
- NO PROBLEM
ACCOMPLISHMENTS

- BALL STUD DESIGN - COMPLETE
- SEAL REQUIREMENTS - COMPLETE
- BEARING ARRANGEMENT - 50%
- HOUSING - 25%
- LUBRICATION - 0%
BEARINGS AND LUBRICATION

• WE CHOSE A HARDENED STEEL UPPER BEARING BECAUSE OF ROBUSTNESS. THE APPLICATION (COMMERCIAL FLEET) PLACES A HIGH PRIORITY ON DURABILITY AND IS WILLING TO SACRIFICE SOME ROTATING TORQUE

• WE NOW NEED TO CHOOSE A LOWER BEARING
LOWER BEARING - STEEL OR PLASTIC?

- STEEL / POWDERED METAL
  - BETTER WEAR
  - LESS COMPLIANCE

- NYLON
  - NOISE ISOLATION
  - LESS EXPENSIVE
  - MORE COMPLIANCE
  - LESS MASS
  - LOWER FRICTION

NYLON IS CHOSEN
GREASE SELECTION

• LUBRICANT IS AN ESSENTIAL ELEMENT OF JOINT DESIGN
• GREASABLE VS. NON-GREASABLE
• TRIBOLOGY STUDIES
• COSTS
FINISHING THE MACHINED FORGING DESIGN

- INTERNAL/EXTERNAL THREADS
- STEM LENGTH
- STEM ANGLE
- MATING FASTENERS
- “COBRA” SECTION

**INPUT REQUIREMENTS**
- LOADS **7000 MAX, 4000 WORKING**
- STEM ANGLE **90 DEGREES @ CURB**
- PACKAGE REQUIREMENTS STRAIGHT, **150MM LONG**
- APPEARANCE PROTECTION **240 HR SALT SPRAY**
- MATING PARTS DETAIL
  - ROD / SLEEVE THREAD SIZE & LENGTH **M16X1.5**
LENGTH ADJUSTMENT FOR TOE SET

• RACK AND PINION JAM NUT
• INNER END ROTATES
• 1.5MM/REV
DETAILING THE MACHINED FORGING

- STEM ANGLE & LENGTH ARE GIVEN
- COBRA THICKNESS & LENGTH DEFINED BY “A”, “B” AND “C” TOOL RADIUS
- D=2.5*THD SIZE +TOE ADJUST
- E FOR PILOT HOLE + THREAD RUN OUT
- F= WASHER FACE OF MATING JAM NUT
FORGING DESIGN - ADDING WHAT WE WILL MACHINE AWAY

- FORGING TOLERANCES +/- .75MM
- DRAFT ANGLES – 7-9 DEGREES
- DIE SHIFT .75MM
- ANGULAR +/- 2 DEGREES
- E-COAT BEFORE MACHINING
QUOTATION CHECKLIST

• FORGING
  – DRAWING COMPLETE RFQ ISSUED

• BALL STUD
  – DRAWING COMPLETE RFQ ISSUED

• SEAL
  – DRAWING COMPLETE RFQ ISSUED

• BEARINGS
  – DRAWING COMPLETE RFQ ISSUED

• MACHINING / ASSEMBLY
  – TIME STUDIES COMPLETE

• PACKAGING
  – 2000 PIECE BULK - NEED PROTECTIVE COVER
PACKAGING

• PROTECTIVE COVER
  – MUST NOT FALL OFF IN TRANSIT
  – MUST COME OFF EASILY AT ASSY PLANT

• COST OF EXPENDABLE SHIPPING CONTAINER

PROTECTIVE COVER
CONGRATULATE YOURSELF

• DESIGN IS DONE
• PART IS QUOTED
• READY TO START PROTOTYPES