Roll Pass Design
Merchant
Channels

Steel of West Virginia, Inc.

Steel Dynamics, Inc.®

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Design: More like a Map than a Recipe.

3 Stages
of
Design

Each step clarifies Vision

DEFINE

Establish overall concept and requirements, challenges, constraints, answering specific questions.

- Tolerances
- Reduction Ratio, # of passes, Avg. Reduction %
- Mill limits,
- Elongations, limits on Mill, Thru put, Cost/Profit
- Special equipment needs
- Ect.

EXPLORE

Playing with the possibilities that fit inside the defined envelope. Take basic design concepts and build structure or composition.

- Quick sketches
- Imagining different possibilities *(Diagonal, T&G, Universal, Slab, Edger, Combo)*
- Start small and quick, move to full size
- Start with KNOWN
  and
  Move toward UNKNOWN

REFINE

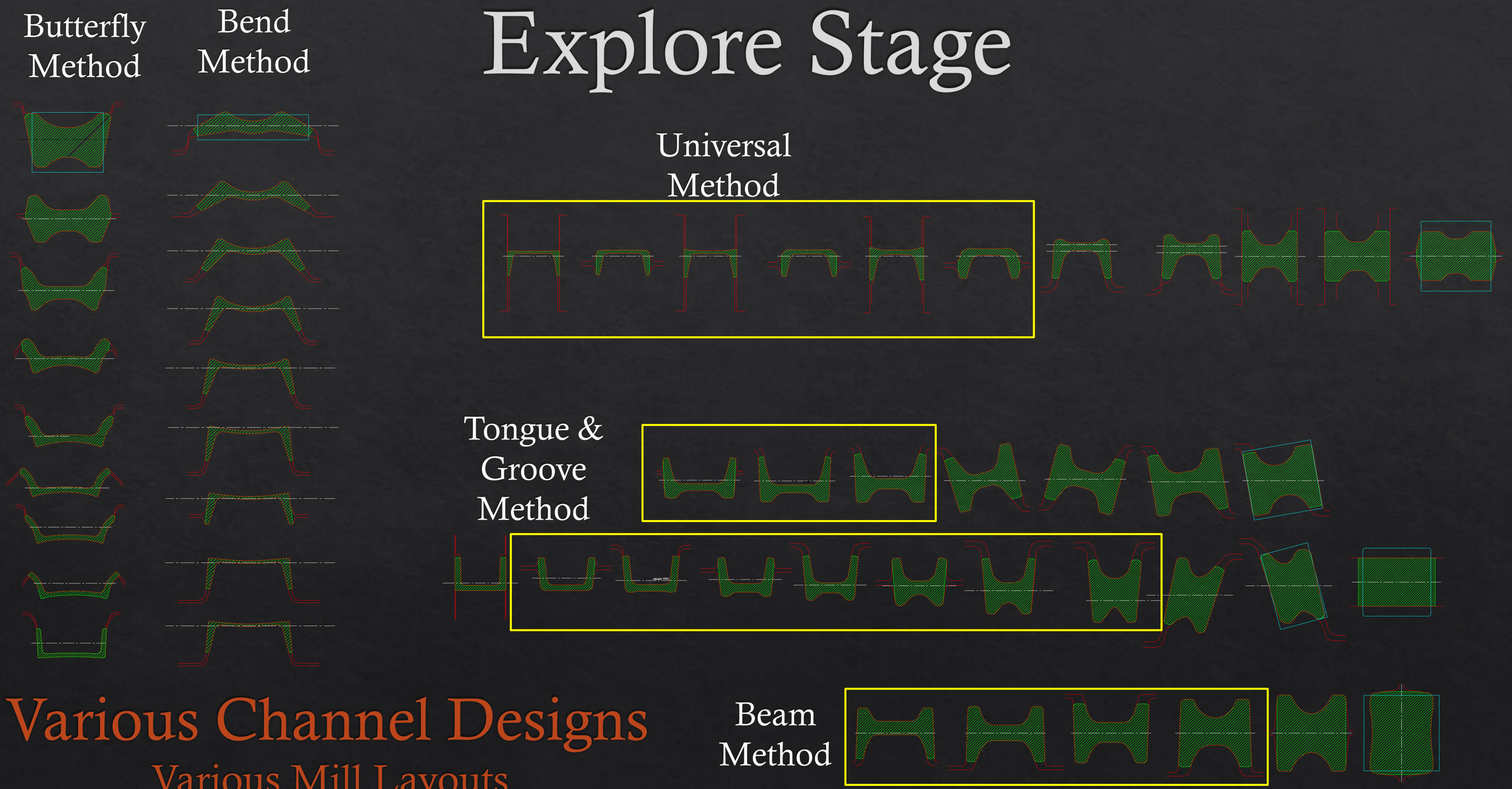
Refining our design to make it balanced and sing.

- Trail and error, adjusting angles, radii, balancing parts of a pass, tracking
- Each Design has a "Money Pass"
  i.e. A stupid pass if it makes it through here we'll be fine.
  Earlier the better!
- Lots of back and forth between Explore and Refine Phases.

Define Stage

- "C" shapes: Channel with inside flange surfaces that have a slope of approximately $16\frac{2}{3}\%$
- "MC" shapes: Channels that cannot be classified as "C" shapes (basically some other slope, typically 2 degrees but can be something else)
- Elongation total: $E^t = \frac{Area\ IN}{Area\ OUT}$: same as Reduction Ratio, also how many times longer than incoming billet final run out will be.
- Reduction Ratio: At least 4:1 to break dendrites in cast billet
- Elongation Average: $E^{avg.} = (E^t)$^$(\frac{1}{\#\ of\ Pass})$
- % Reduction Average: $\frac{E^{avg.-1}}{E^{avg.}}$
- Reduction %: $\frac{(Area\ IN - Area\ OUT)}{Area\ IN}$
- Run Out: (Final Cut Lengths x Mults + crops) x 1.012 (hot size)
- Billet Length: $\frac{Run\ Out}{E^t}$
- Constraints ? : Furnace billet lengths, table roller dist., Inter-stand distance, ect.

Explore Stage

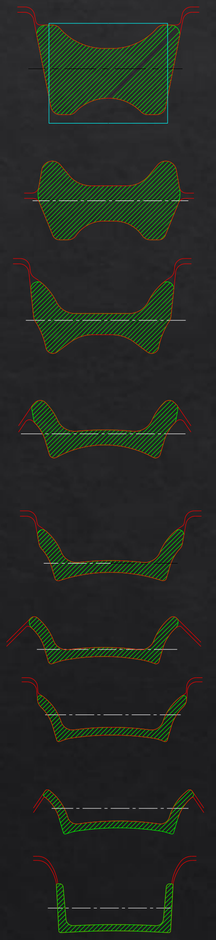


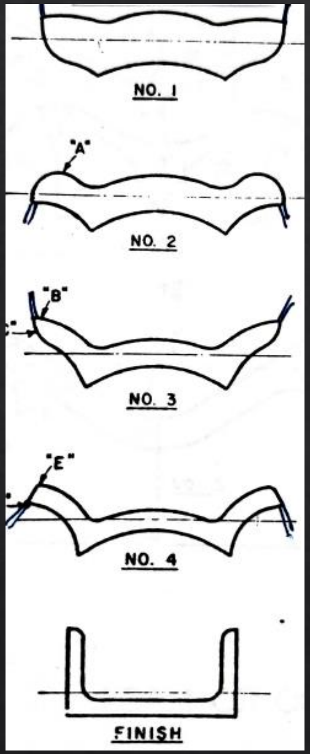
Various Channel Designs

Various Mill Layouts

Butterfly Method:

Flanges & web are arched. Toe joints alternate, controlling fins, while edging opposite toe radii. Direct or near direct rolling of both web and flanges. Bending of flanges into position typically saved to last few passes. Good for wide channel relative to the flange depth





Advantages

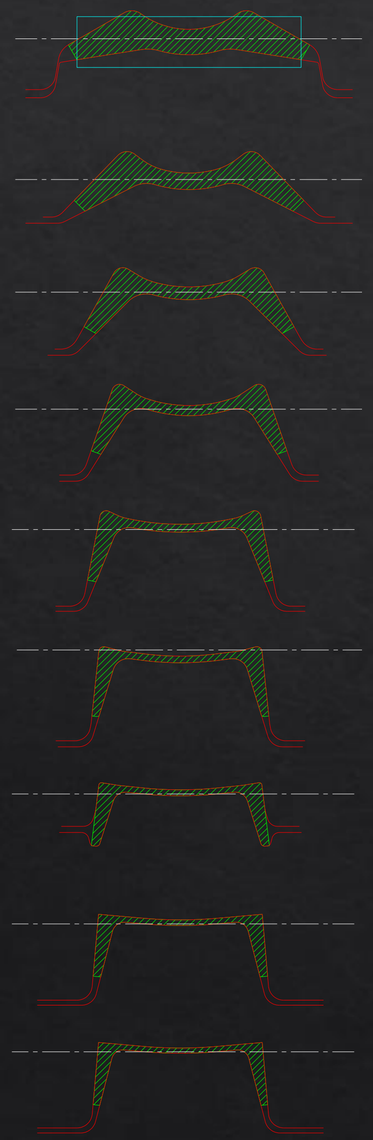
- Direct rolling of flanges and web,
  i.e. good physical properties
- Flanges are entirely made in live holes
  - Great work, and fewer passes, than beam method
- Passes remain shallow
  i.e. increased roll life
- Increased yield due to similar flange & web work (less web tongue)
- Plate radii controlled

Disadvantages

- Less effective at producing various weigh-ups than other methods
  - An increase in web parting, greatly increases flange thicknesses
- Flared out flanges consumes more roll barrel (width)
- Guiding on entering slab, and final folding passes are crucial for uniform flange development

Bend Method:

Flanges straight & web is arched. Progressive folding (or Bending) in each Pass. Good for channel with deep flanges relative to the channels width.



Advantages

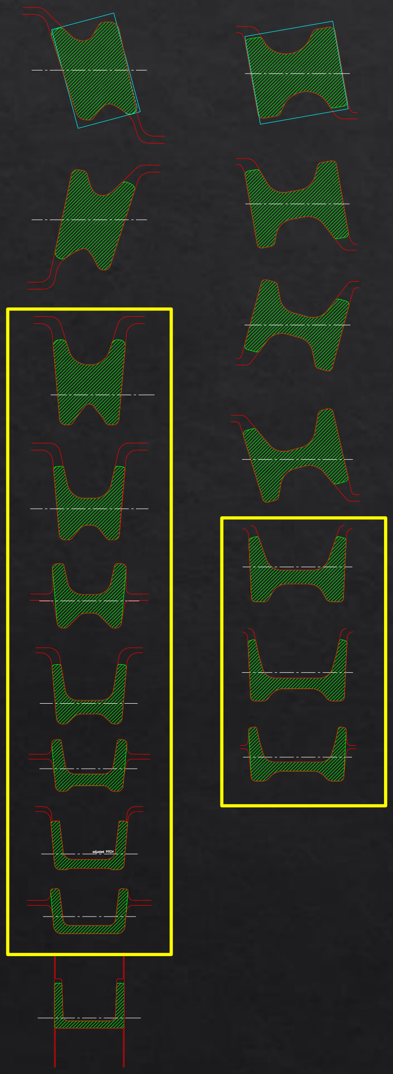
- Direct rolling of flanges and web, i.e. good physical properties
- Usually enters with Slab pass from Rougher Train
- Reduces wedging effect that can occur in Tongue and Groove & Beam Method
- Flanges are mostly made in live holes, occasional edger pass to work toes, Plate radii controlled
- Increased yield due to similar flange & web work (less web tongue)
- Good for deep parallel flanges

Disadvantages

- Less effective at producing various weigh-ups than other methods
    - An increase in web parting, greatly increases flange thicknesses
- Flared out flanges consumes more roll barrel (width)
- Wiping tendency
- Wears rolls quicker
- Guiding and tracking can be temperamental due to bending action, rounded collars can help

Tongue & Groove Method:

Good all around channel design method. After "knifing" of billet into a beam; web is reduced, while flanges are pushed up. Over all width is often consistent, Flange tongue gradually increases in width, while counter flanges or "kick-ups" (The beam which are rolled off to form channel) are used to grow flange height. Edger passes work toes.



Advantages

- Shared rougher passes w/ I-Beam's
  ie reduced roll inventory for beams and channel families
- Bar self tracks, & good overall surface condition
- No bending action!
- Simple guiding required
- Easy to set up, minimal roller adjustments, gap and go.
- Nearly no place to overfill

Disadvantages

- Tendency to wedge and collar if too much work is applied
- Wiping tendency, due to indirect rolling, & dissimilar roll dia. speeds
- In-direct rolling of flanges
- Large tongue can develop due to web reduction
- Deep passes require special tooling to clean up

Universal Method:

Most flexible method. Typically started with a box pass, Universal passes offer direct rolling with minimal wear. Flanges are made with universal stands, work is directly rolled from outside using cassettes, Edger passes are used to work toes, and protect against overfills in proceeding pass.

Advantages

- Best Method for varying weights
- Best Roll Life
- No bending action!
- Roll cost often less
- Simple guiding required

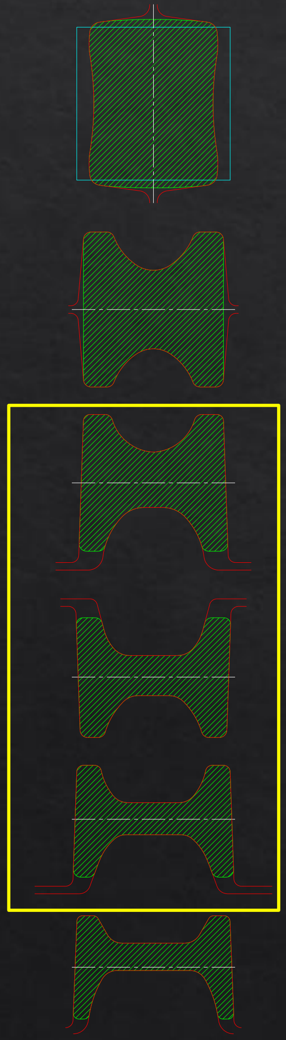
Disadvantages

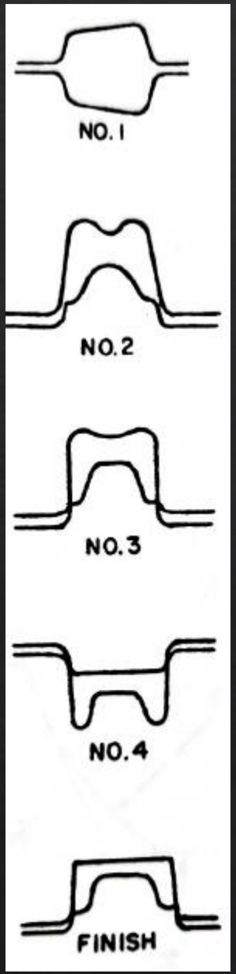
- More variations on setup introduced
- Overfills or laps on plate are possible
- Difficult time narrowing billet without creating flanges.

Beam Method:

(Typically used for Break down only)

European method of Beam development. I typically use for a beam and channel break down followed by T&G or Universal method. Web is reduced, while flanges alternate between dead and live legs. Dead legs work the end of flanges, and protect from overfilling, in proceeding Live leg joint, which narrows flange with wider tongue. Flanges are bent back and forth vertically.





Advantages

- Shared rougher passes w/ I-Beam's
  i.e. reduced roll inventory for beams and channel families
- Can be used on over under passes
  i.e. Shared Groove or Tongue; Helpful when barrel width can be limited
- Works well at widening

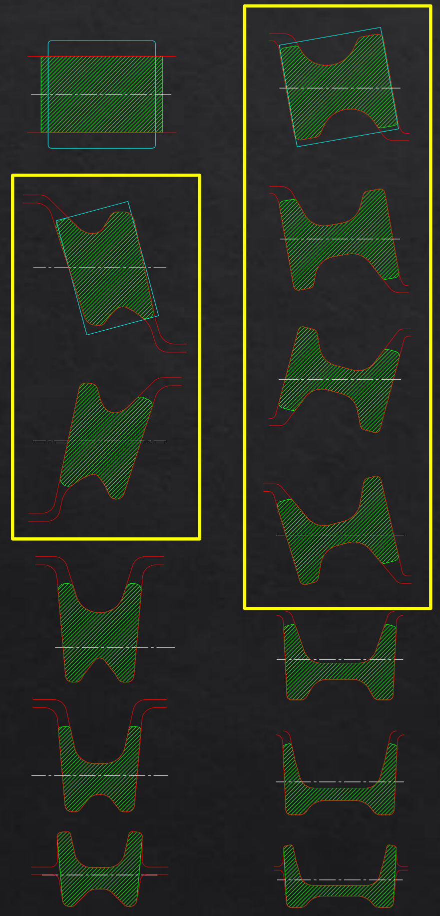
Disadvantages

- Flanges wear and grow wide
- Collar Tendency
- Wiping tendency
- Overfill potential
- Deep and steep passes difficult to clean up

Diagonal Method:

(Typically used for Break down only)

My favorite method of Beam development. I typically use for a beam and channel break down followed by T&G or Universal method. Web is reduced, while flanges alternate between dead and live legs. Dead legs are side opposite, alternating to Live legs



Advantages

- Shared rougher passes w/ I-Beam's
  i.e. reduced roll inventory for beams and channel families
- Decrease roll wear
- Removes collaring tendency of European Beam method, Each roll has dead leg and half life leg
- Can be used to roll parallel flange channel without universal mill stand
- Works well at widening or narrowing
- Easy to set up, minimal roller adjustments, gap and go.

Disadvantages

- Twist potential
- Guide setup critical
- Less pass flexibility

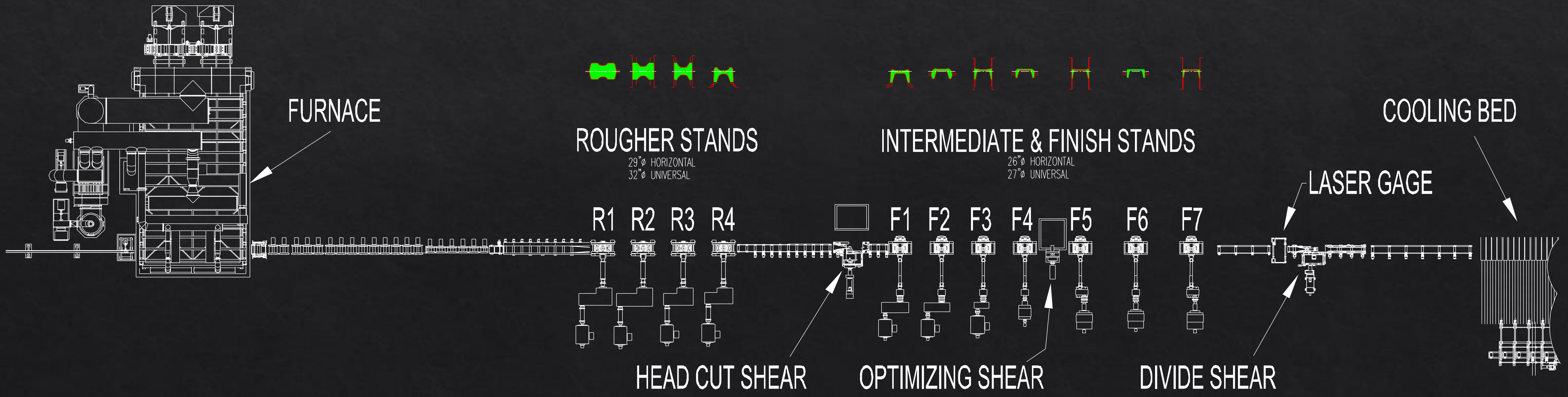
Building “Blocks” for Designing Complex Shapes

The following 3” channel design uses these types of “blocks”

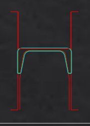
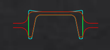
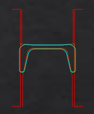
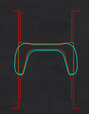
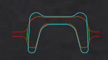
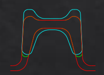
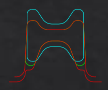
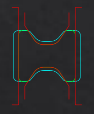
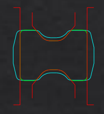
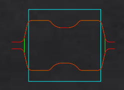
- Slab
- Box
- Tongue & Groove
- Edger
- Universal
- Diagonal
- Beam
- Butterfly
- Bend

SWVA #2 Mill

- Bricmont Pusher Furnace
- Rougher Train: 4 Quad cartridge stands inline (R1-R4) 29.5" pitch x 24" barrel or 32" dia. donuts
- Intermediate & Finish Train: 7 Quad cartridge stands inline (F1-F7) 26" pitch x 32" barrel or 27" dia. donuts
- 11 Mill stands in total
- Cooling Bed, Straightener, Flying Shear, Stackers: NOT SHOWN

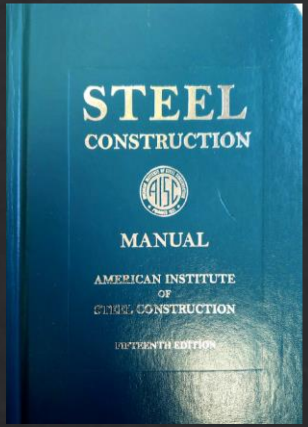


C3 Pass Design Overview

	FINISHING STANDS F5–F7				INTERMEDIATE STANDS F1–F4					ROUGHING STANDS R1–R4			
DESCRIPTION	F7 UNIVERSAL	F6 EDGER	F5 UNIVERSAL	OPTIMIZER SHEAR	F4 EDGER	F3 UNIVERSAL	F2 EDGER	F1 T & G	HEAD CUT SHEAR	R4 T & G	R3 UNIVERSAL	R2 UNIVERSAL	R1 BOX
C3x3.5													
C3x4.1	WEB +0.040"	WEB +0.040"	WEB +0.040"										
C3x5.0	WEB +0.129"	WEB +0.129"	WEB +0.129" CASS. +.020"		WEB +0.130"	WEB +0.130"	WEB +0.100"	WEB +0.058"					
C3x6.0	WEB +0.228"	WEB +0.228"	WEB +0.228" CASS. +.010"		WEB +0.229"	WEB +0.229"	WEB +0.200"	WEB +0.150"		WEB +0.150"			

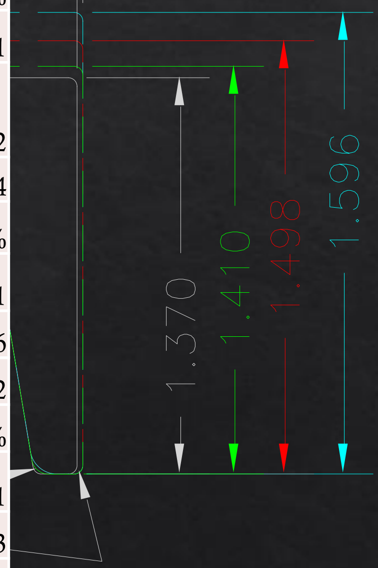
C3 Define stage

- Draw all weigh-ups see AISC or ASTM Manual
- Determine Radii for weight
- If necessary adjust within tolerances, for roll commonality
  Ex: C3x#3.5 common tongue, universal cassette width narrowed for this weigh-up
- Set Tolerances Again, See AISC or ASTM for standards
- Determine known variables:
  mult lengths, E^t, $E^{avg.}$ # of passes, Billet size and length, ect.



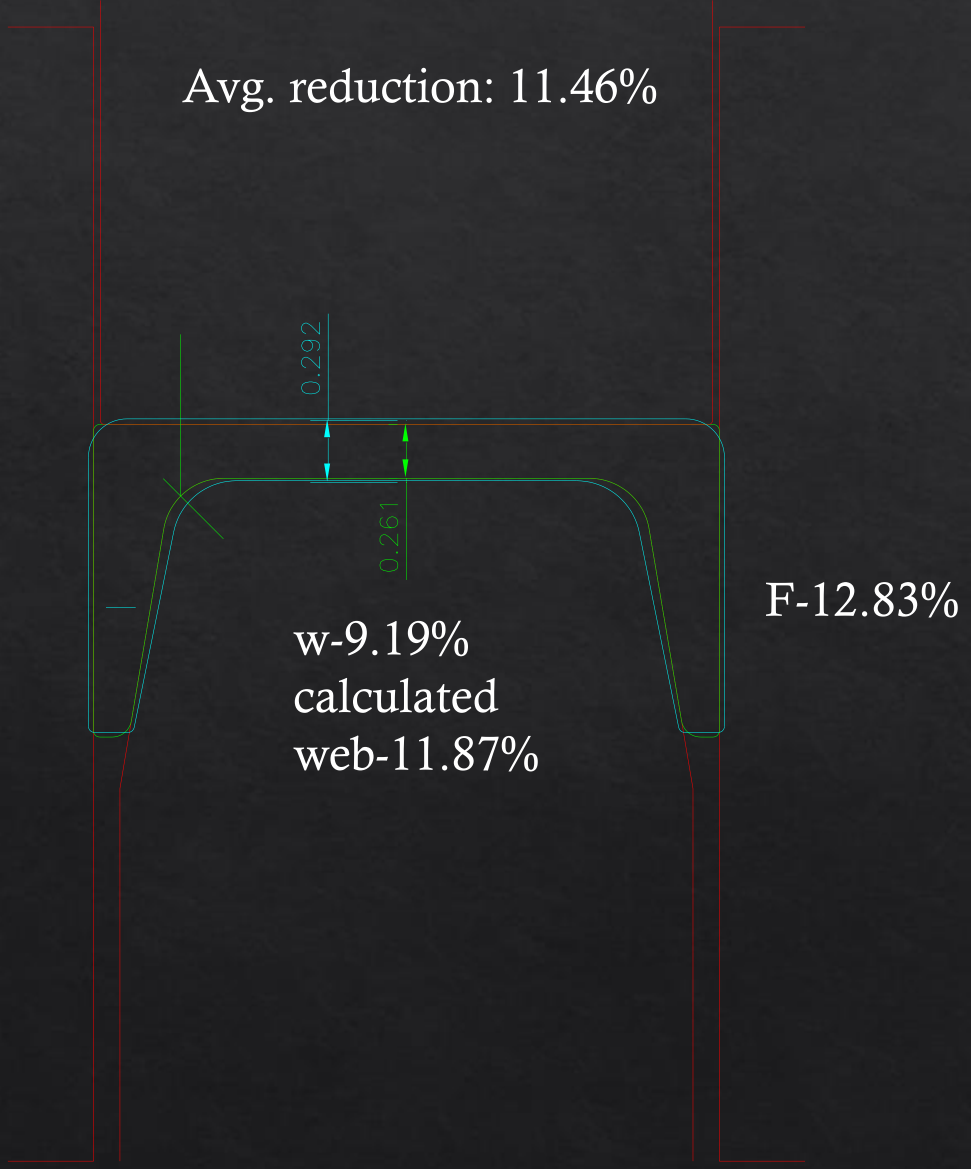
C3×6	1.76	3.00	3	0.356	3/8	3/16	1.60	1 5/8	0.273	1/4	11/16	1 5/8	—	0.519	2.73
×5	1.47	3.00	3	0.258	1/4	1/8	1.50	1 1/2	0.273	1/4	11/16	1 5/8	—	0.495	2.73
×4.1	1.20	3.00	3	0.170	3/16	1/8	1.41	1 3/8	0.273	1/4	11/16	1 5/8	—	0.469	2.73
×3.5	1.09	3.00	3	0.132	1/8	1/16	1.37	1 3/8	0.273	1/4	11/16	1 5/8	—	0.455	2.73

[g] The actual size, combination, and orientation of fastener components should be compared with the geometry of the cross-section to ensure compatibility.
— Flange is too narrow to establish a workable gage.



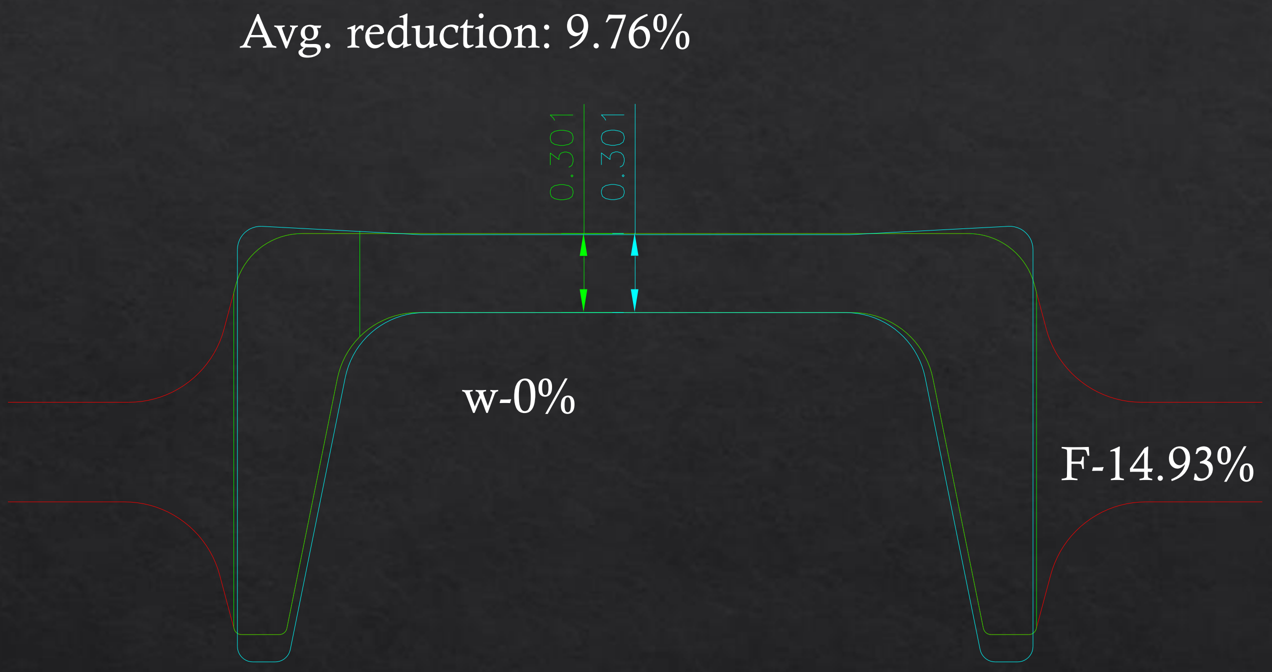
C3x3.5	Elong. Total	15.45849
	Elong. Avg.	1.283
AREA	% Reduction Avg.	22.036%
1.060	# OF PASSES	11
C3x3.5	Elong. Total	13.21452
	Elong. Avg.	1.264
AREA	% Reduction Avg.	20.916%
1.240	# OF PASSES	11
C3x3.5	Elong. Total	10.87326
	Elong. Avg.	1.242
AREA	% Reduction Avg.	19.502%
1.507	# OF PASSES	11
C3x3.5	Elong. Total	9.058043
	Elong. Avg.	1.222
AREA	% Reduction Avg.	18.154%
1.809	# OF PASSES	11
BILLET	4x4	

C3 Stand F7 (finish)



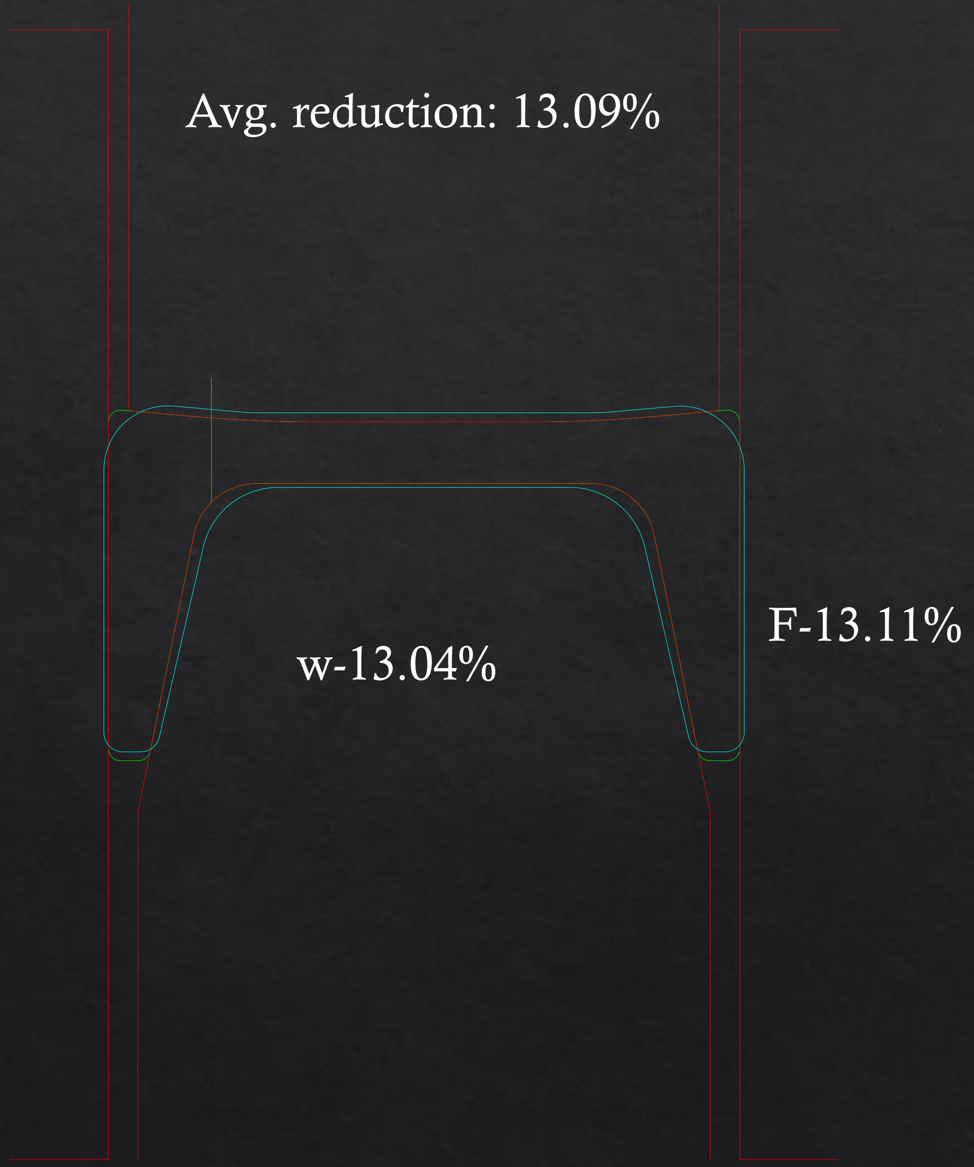
- Hot size ie Thermal Expansion Factor. I use 1.012
- F7-Universal pass; which sets Final dimension, except live joints
- Gazinta (F6) will be Edger style which controls universal live joints
  1. Inside angle increased ~ 2°
  2. Set inside flange tracking ½ to ¾ flange length.
  3. Add work to outside of flange to get desired area reduction
  4. Multiply web thickness by desired percentage of web reduction. Typically 0-1% less than flanges (this keeps web in tension) more critical on wide channel
  5. Increase web radii by ~0.125"
  6. Set plate radii or chamfers typically tangent to largest allowable final plate radii. Chamfers offer more joint protection
  7. Set entering flange length allowing for spread
  8. Divide bar flanges and Web check reductions, adjust accordingly, trust calculated web over flange subtraction from total area

C3 Stand F6 (pre-finish)



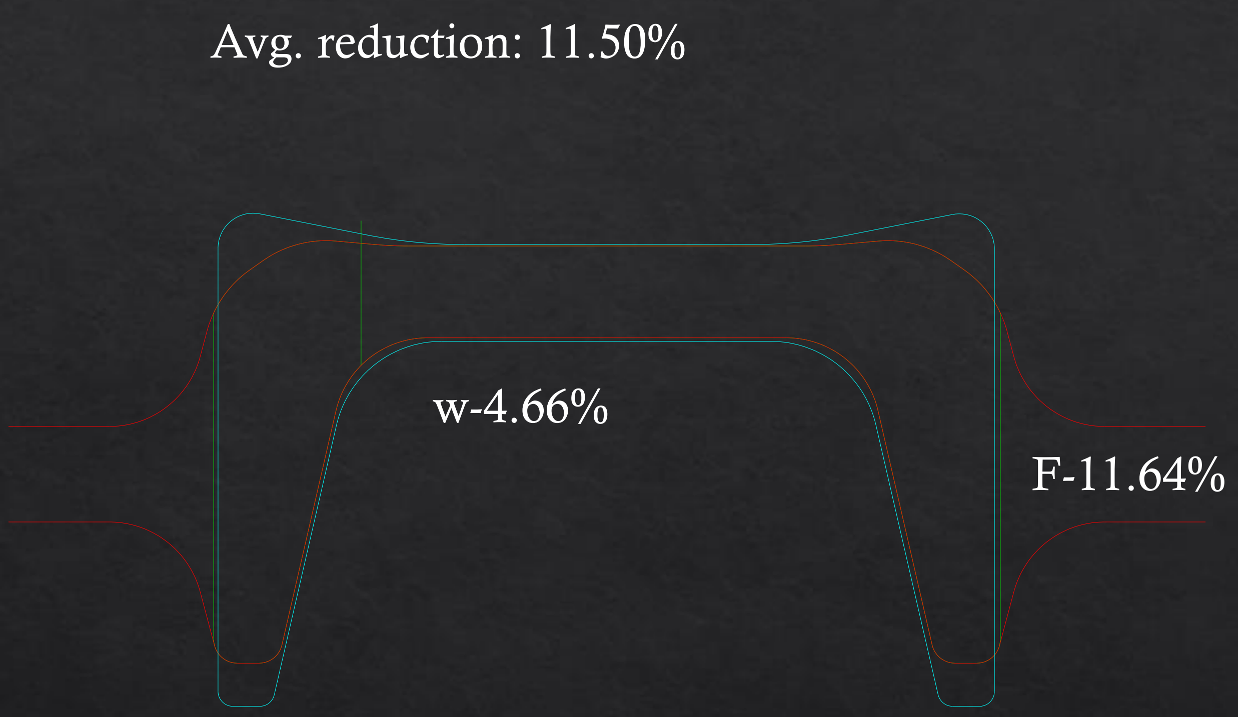
- F6- Edger pass which controls plate radii and flange length
- Gazinta (F5) will be Universal style
  1. Inside angle remains the same
  2. Add edging work to toes ~ ½ flange thickness
  3. Inside flange work ½ to ¾ distance of edging work. Ex. 1/8" edging work = 1/16" inside flange work .
  4. Kick-ups start here. Typically kick-ups from Universals are for the purpose of Joint protection. Which sharpen plate radii
  5. Set flange width less the amount of spread
  6. No web work here
  7. Divide bar flanges and Web check reductions, adjust accordingly

C3 Stand F5



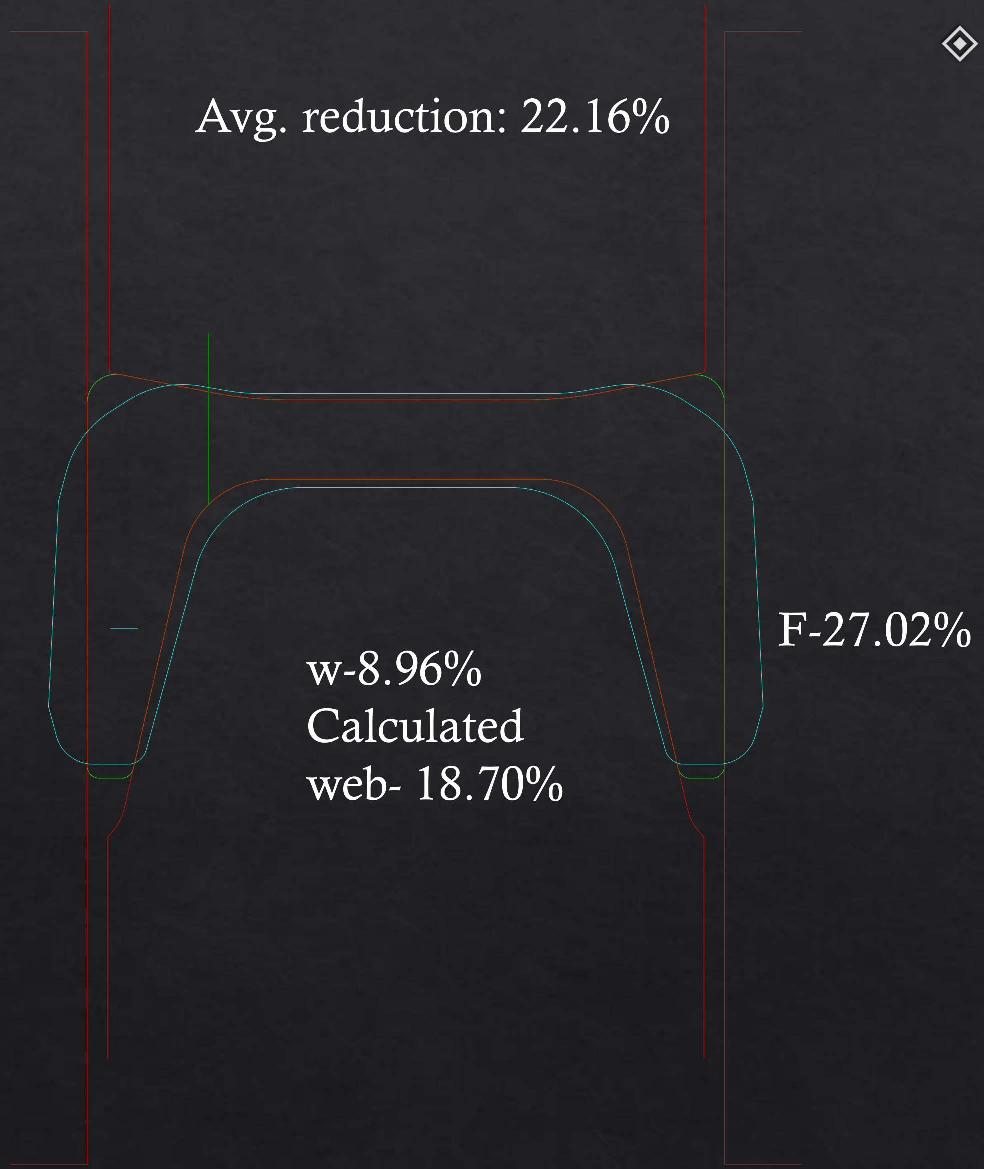
- F5-Universal pass; which thins and lengthens flanges, sets web work for F7.
- Gazinta (F4) will be Edger style which controls universal live joints
  1. Design Gazinta same as F7.
  2. Divide bar flanges and Web check reductions, adjust accordingly. Aim for more work than finish pass, keep flange to web reductions close, slightly more flange
  3. Too much flange work will result in tendency to overfill, or wavy flanges
  4. Too much web work will result in large plate radii or washboard

C3 Stand F4



- F4- Edger pass: Which controls plate radii and flange length, some web work is done here.
- Gazinta (F3) will be Universal style
  1. Design Gazinta same as F3, but with some web work.
  2. Chamfers used on plate radii, to better prevent overfills in proceeding Universal pass
  3. Set flange width less the amount of spread
  4. Divide bar flanges and Web check reductions, adjust accordingly

C3 Stand F3

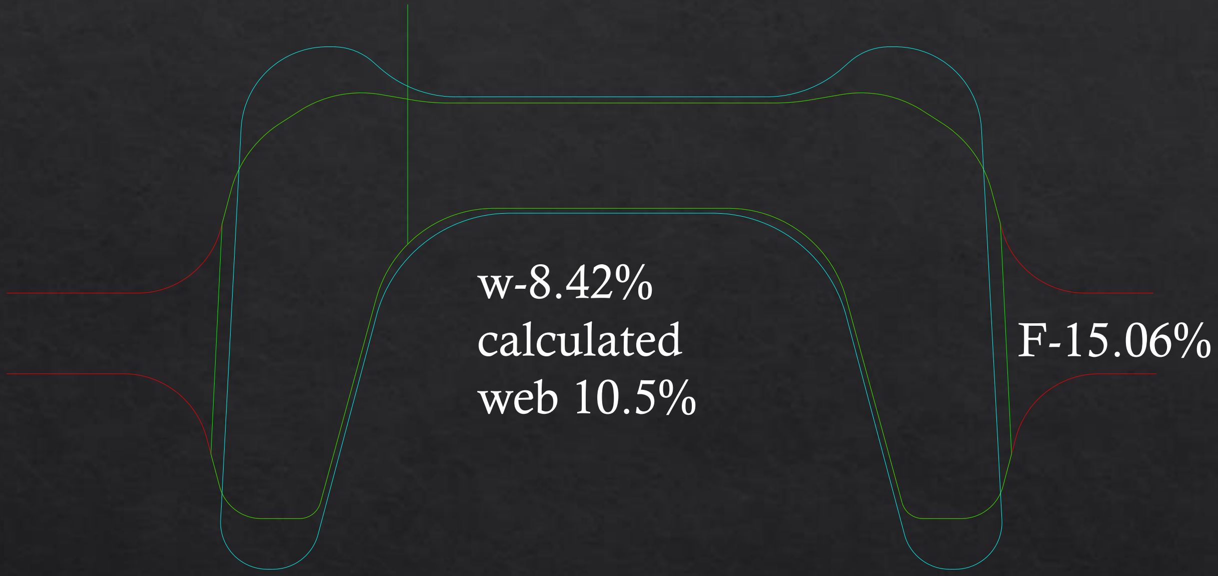


- F3-Universal pass: Which thins and lengthens flanges, sets web work for F4. Primary thinning pass after T&G.
- Gazinta (F2) will be Edger style: Which drives legs down, protecting against plate radii overfill

1. Inside angle increased. Keep in mind outside has angle Net flange angle same F3
2. Set inside flange tracking ½ to ¾ flange length.
3. Add work to outside of flange to get desired area reduction, due to F2 edging T&G outside angle should be ~3°
4. Multiply web thickness by desired percentage of web reduction. With small channel compare avg. reduction and flange reduction
5. Increase web radii by ~0.125”
6. Set plate radii as chamfers, don’t depend on spread for edging work in F
7. Set entering flange length allowing for spread
8. Divide bar flanges and Web check reductions, adjust accordingly, trust calculated web over flange subtraction from total area

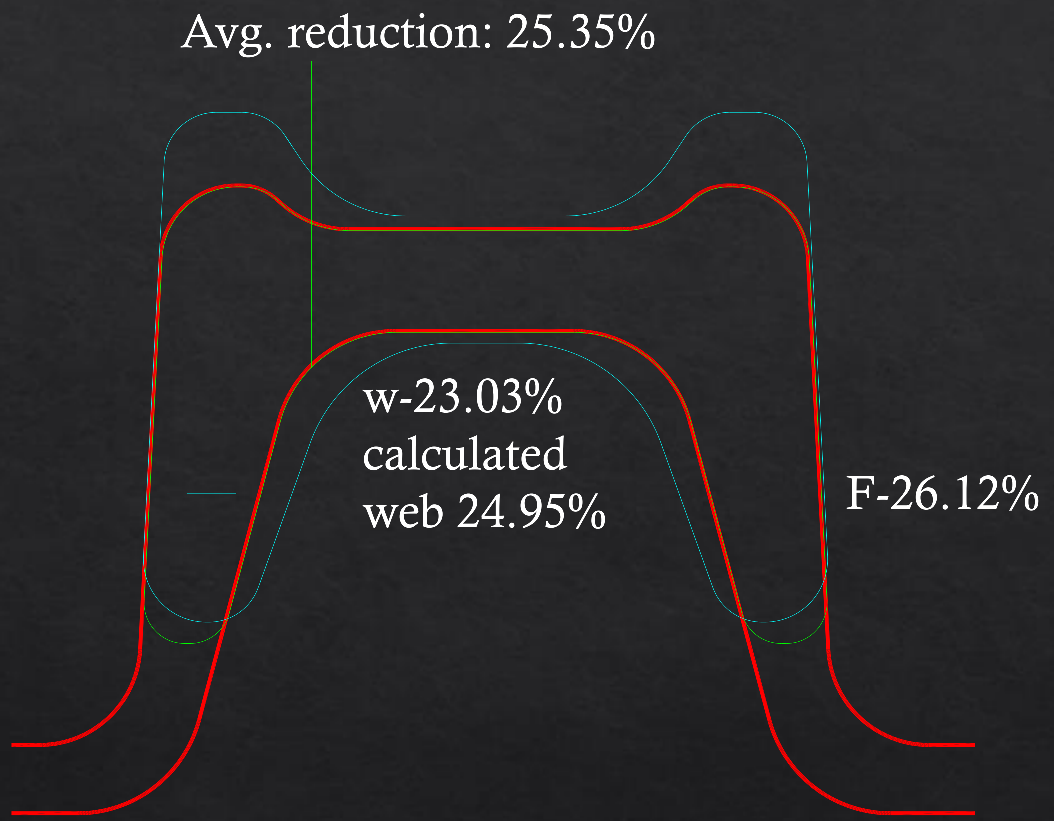
C3 Stand F2

Avg. reduction: 13.37%



- **F2- Edger pass:** Converts final kick-ups into chamfers, sets leg height.
- Gazinta (F3) will be Tongue & Groove style
  1. Inside angle remains the same
  2. Add edging work to toes ~ ½ flange thickness
  3. Edging kick-ups pretty aggressively, Big plate radii on kick-ups prevents lap
  4. Pinched toes, controls flanges, while allowing spread.

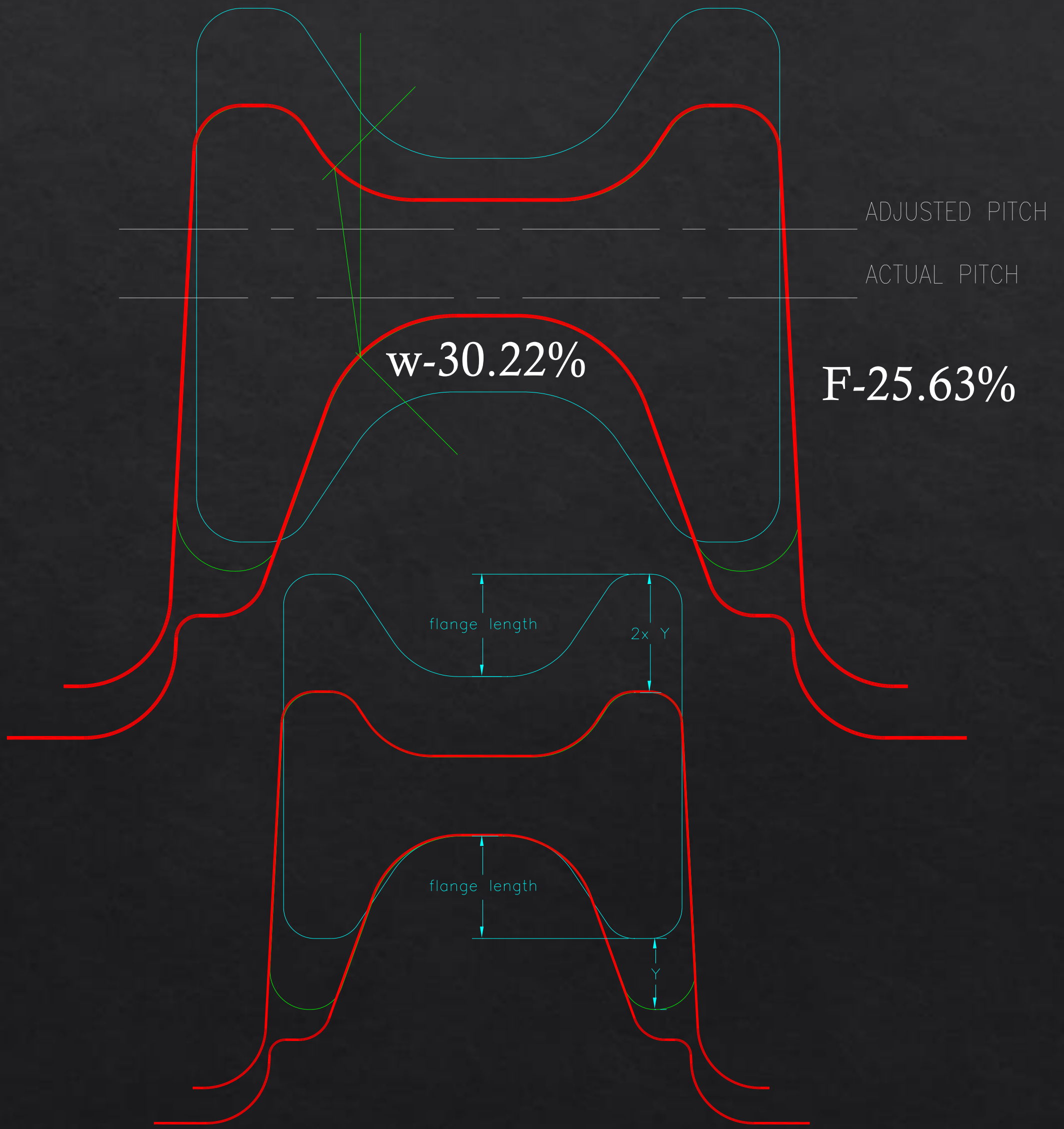
C3 Stand F1



- F1- Tongue & Groove: Drives legs downward, creates flange length, and uses kick-ups to do so.
- Gazinta (R4) will be Tongue & Groove style
  1. Increase inside angle ~5°
  2. Groove side walls set at 3°
  3. Set inside flange tracking ½ to ¾ flange length
  4. Outside work tracks even @ ¼ to ½ kick-up
  5. Kick-ups will typically gain ½ flange height $^5/_{16}$ kick-ups will net approx. $^5/_{32}$ flange gain.
  6. Calculate web work, to keep within 1% flange work

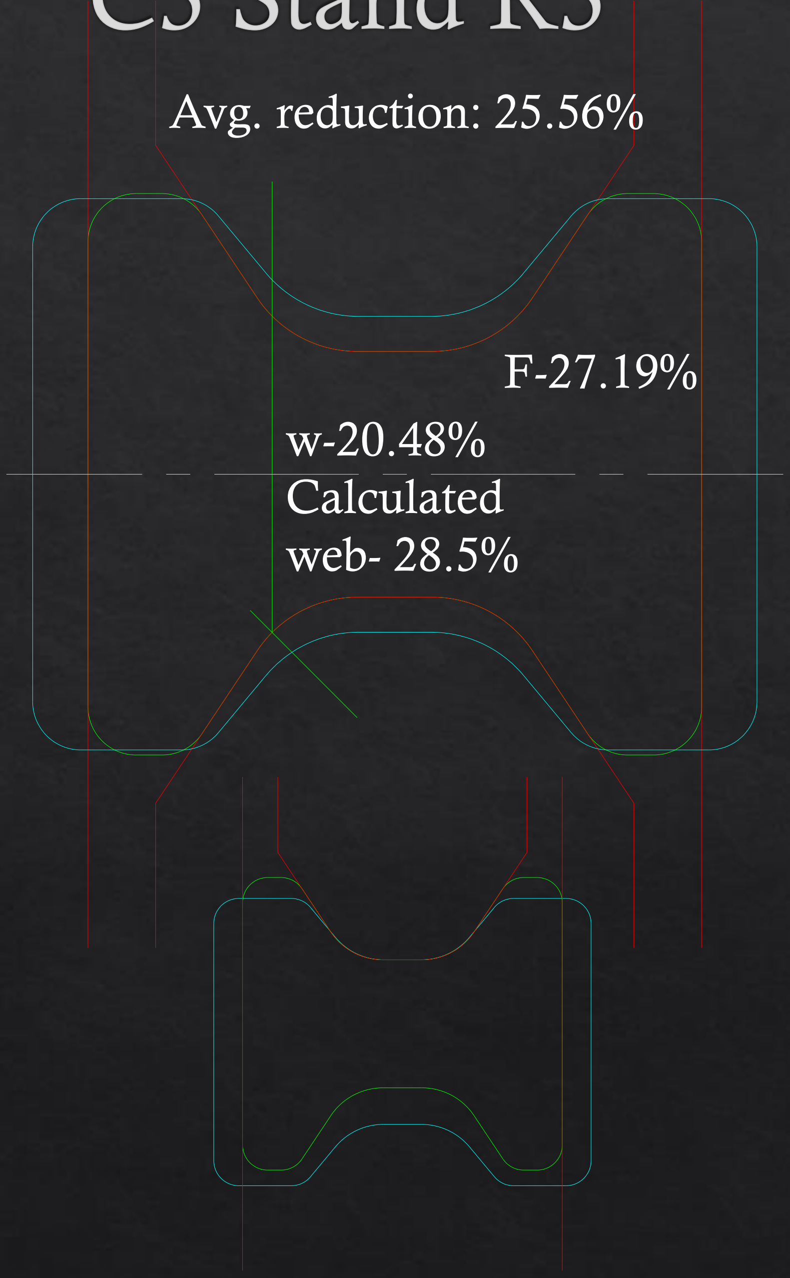
C3 Stand R4

Avg. reduction: 26.82%



- R4- Tongue & Groove: Drives legs downward, creates flange length, and uses kick-ups to do so.
- Gazinta (R3) will be Universal style
  1. Side walls set straight for cassettes
  2. Increase inside angle ~13° net flange change of 10°
  3. Set inside flange tracking ½ to ¾ flange length.
  4. Keep in mind flanges are flaring out
  5. Outside work same width as groove base
- Web has greater effect on kick-ups in rougher
  1. Set web to web for rougher kick-ups from beam
  2. R3 Flange length set ½ to ¾ R4 flange length
  3. Kick-ups double height difference
  4. Extra web work helps retard flange growth
- Adjust pitch to counter groove collar tendency

C3 Stand R3



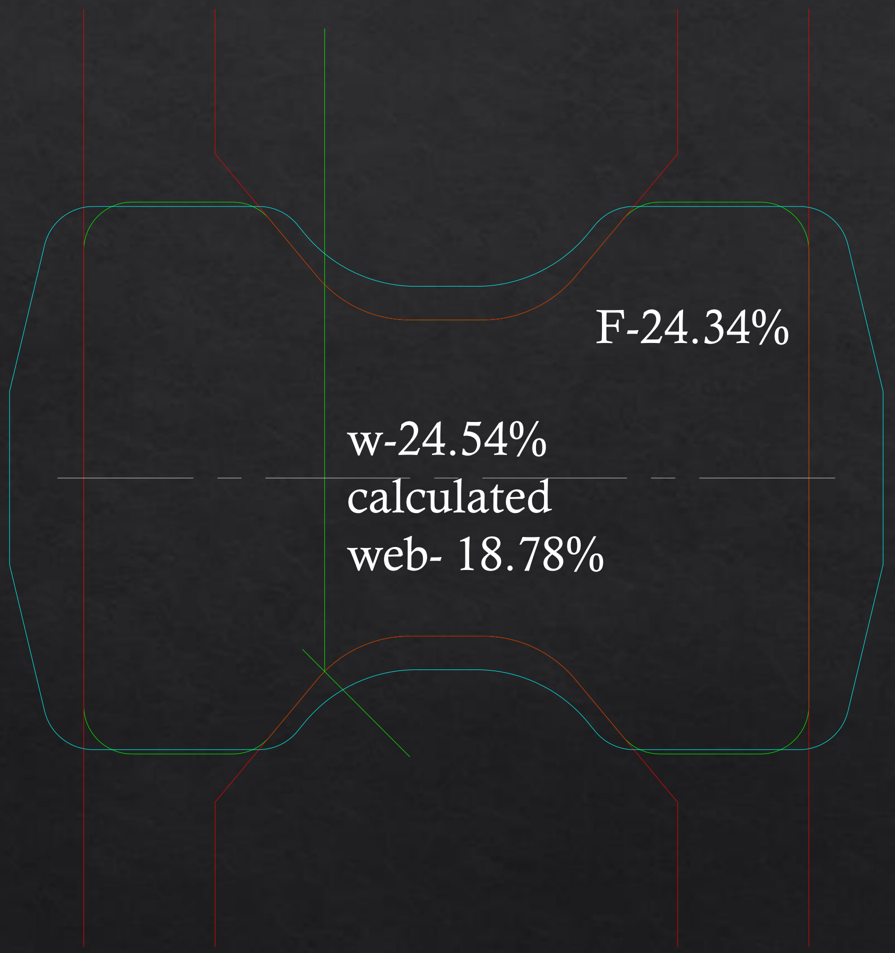
- **R3-Universal pass:** Used to thin beam overall, Width set critical for R4 T&G
- **Gazinta (R2) will be another Universal pass**

Primarily thins web and narrows bar, while creating flanges

1. Inside angle increased ~6˚ Set inside flange tracking ½ to ¾ flange length.
2. Add work to outside of flange to get desired area reduction.
3. Plan spread comparing flange heights (web restriction considered); extra joint protection just in case
4. Web work at rougher stage greater (Steel is more plastic and forgiving while hotter)
5. Beam is set up for upcoming Tongue and Groove pass
6. Divide bar flanges and Web check reductions, adjust accordingly.) trust general web % & universal vs cass. bite angle, over calculated %

C3 Stand R2

Avg. reduction: 20.25%

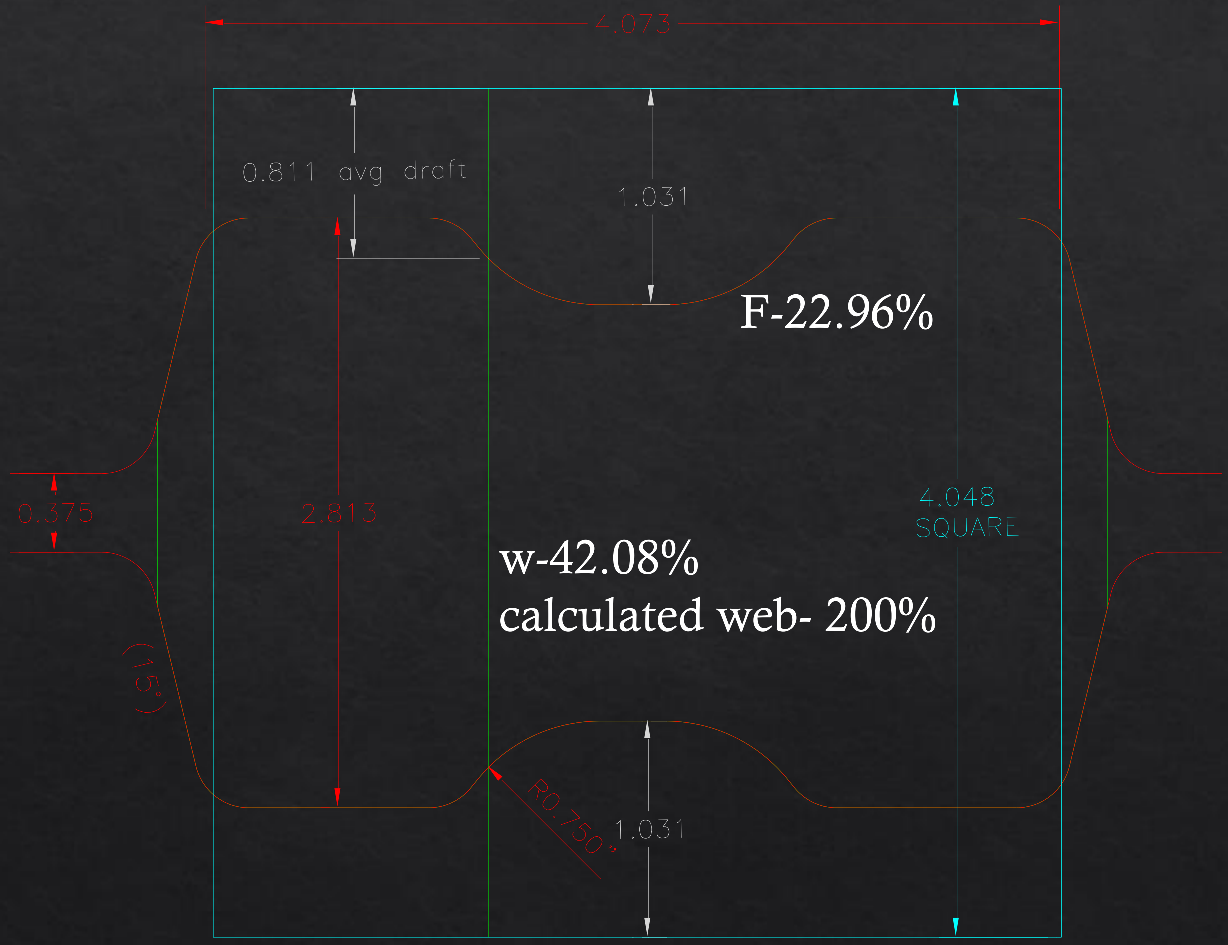


- R2-Universal pass: Used to form beam, and thin width as much as possible
- Gazinta (R1) will be a Box pass: Primarily Slabbing and setting flange to web ratio.

1. Inside angle increased ~6˚ Set inside flange tracking ½ to ¾ flange length.
2. Work on outside of flanges comes from spread in R1
   Remove as much as possible, split between R2 & R3
3. Plan spread comparing flange heights
   (web restriction considered); extra joint protection just in case
4. Get rid of width!
5. Two Universal passes in a row
   (used to knife into billet creating beam and remove overall width)
6. Divide bar flanges and Web check reductions, adjust accordingly)

C3 Stand R1

Avg. reduction: 28.97%



◈ R1- Box Pass: A beam version of elongating pass. Opposite of edger pass, namely more work on web than flanges. Knifes web, creating initial web to flange ratio, also edges flanges

1. Gazinta is Billet, 4x4 in this case.
2. Bite angle is one limiting factor. $\cos\beta^{-1} = \frac{Roll\ \emptyset - \Delta height}{Roll\ \emptyset}$

   Generally speaking Bite angle max ~28°
3. Plan bite angle at deepest pierced point, w/ scrap dia. rolls
4. Box pass set near hot size of entering billet, holds tracking.
5. Flange to web ratio set near as possible to avg. Finished product dimensions
6. Extra web draft retards spread of flanges
7. Flange height determined from R4 flange height
8. Divide bar flanges and Web check reductions, adjust accordingly)

Balancing weigh-ups

SECTION	C3x3.5		
DESCRIPTION:	TOTAL	WEB	FLANGE
pass/stand	REDUCTION	RED.	RED.
F7	19.39%	19.68%	19.28%
F6	8.81%	0.80%	11.61%
F5	18.16%	22.08%	16.69%
F4	14.96%	8.40%	17.18%
F3	27.45%	21.79%	29.19%
F2	17.98%	18.89%	17.70%
F1	28.52%	31.34%	27.59%
R4	26.82%	30.22%	25.63%
R3	25.56%	20.48%	27.19%
R2	20.25%	24.54%	18.78%
R1	28.97%	42.08%	22.96%
BILLET			
4x4			

SECTION	C3x4.1		
DESCRIPTION:	TOTAL	WEB	FLANGE
pass/stand	REDUCTION	RED.	RED.
F7	13.77%	14.91%	13.24%
F6	7.88%	0.22%	11.05%
F5	11.41%	4.79%	13.88%

SECTION	C3x5.0		
DESCRIPTION:	TOTAL	WEB	FLANGE
pass/stand	REDUCTION	RED.	RED.
F7	11.46%	9.19%	12.83%
F6	9.76%	-0.31%	14.93%
F5	13.09%	13.04%	13.11%
F4	11.50%	4.66%	14.64%
F3	22.16%	8.96%	27.02%
F2	13.37%	8.42%	15.06%
F1	25.35%	23.03%	26.12%

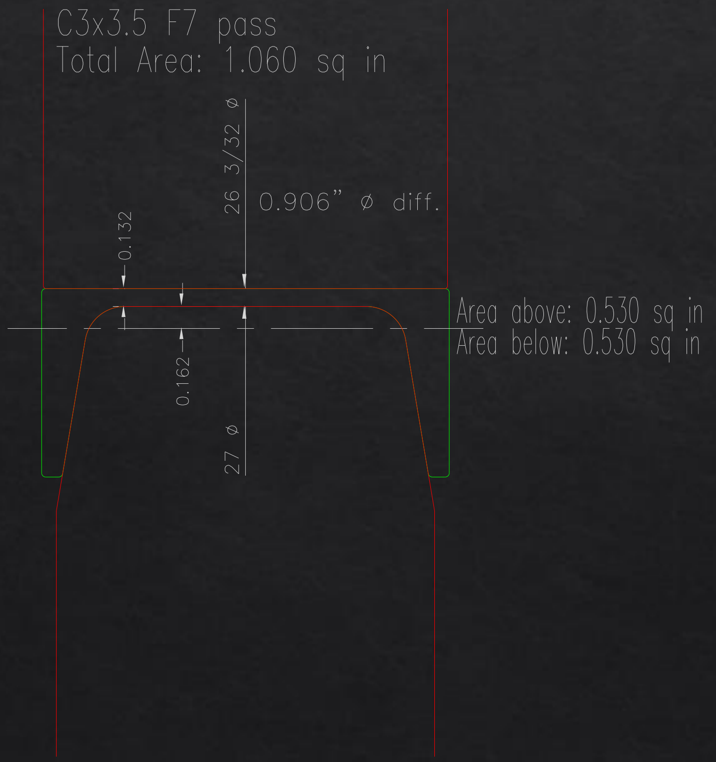
SECTION	C3x6.0		
DESCRIPTION:	TOTAL	WEB	FLANGE
pass/stand	REDUCTION	RED.	RED.
F7	9.73%	5.76%	12.65%
F6	7.01%	-0.35%	11.77%
F5	13.77%	8.83%	16.69%
F4	9.46%	3.63%	12.58%
F3	19.25%	6.04%	24.92%
F2	14.49%	5.44%	17.86%
F1	23.44%	7.97%	27.96%
R4	21.56%	31.61%	18.05%

- Once designed, Adjust for multiple weigh-ups, adjust design accordingly
- Use standard mill adjustments

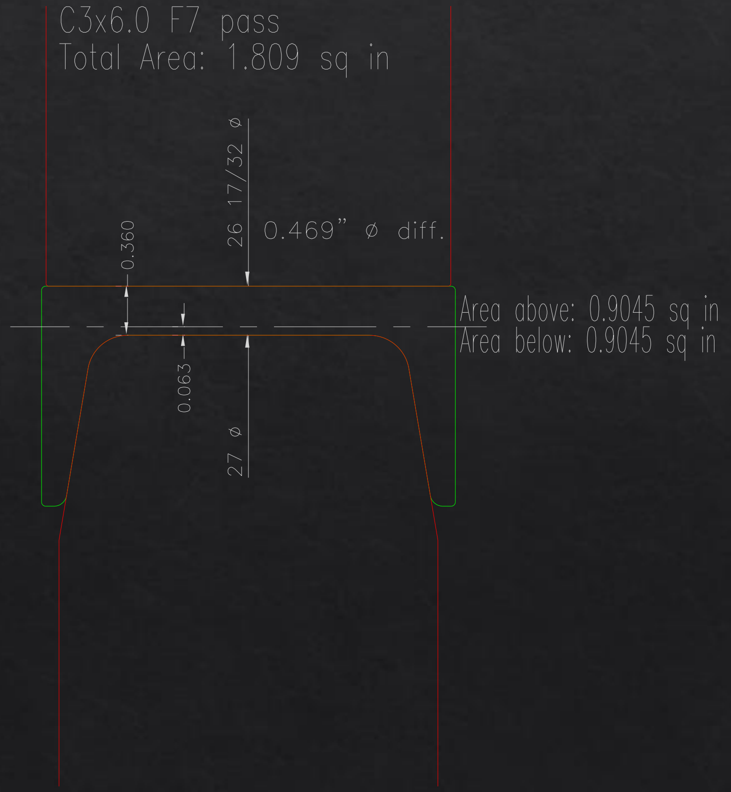
  Make it easy and reproducible for the rollers
- Heavy weigh-ups should target 10% reduction final pass, and step back accordingly
- Light weigh-ups will obviously be more this case 19.35% finished pass
  1. Smaller products can be deceiving 20% of a 0.135” web is only 0.027”
- Set Pitch lines

Set pitch line for lightest weight section

Set Pitch line equal area below and above

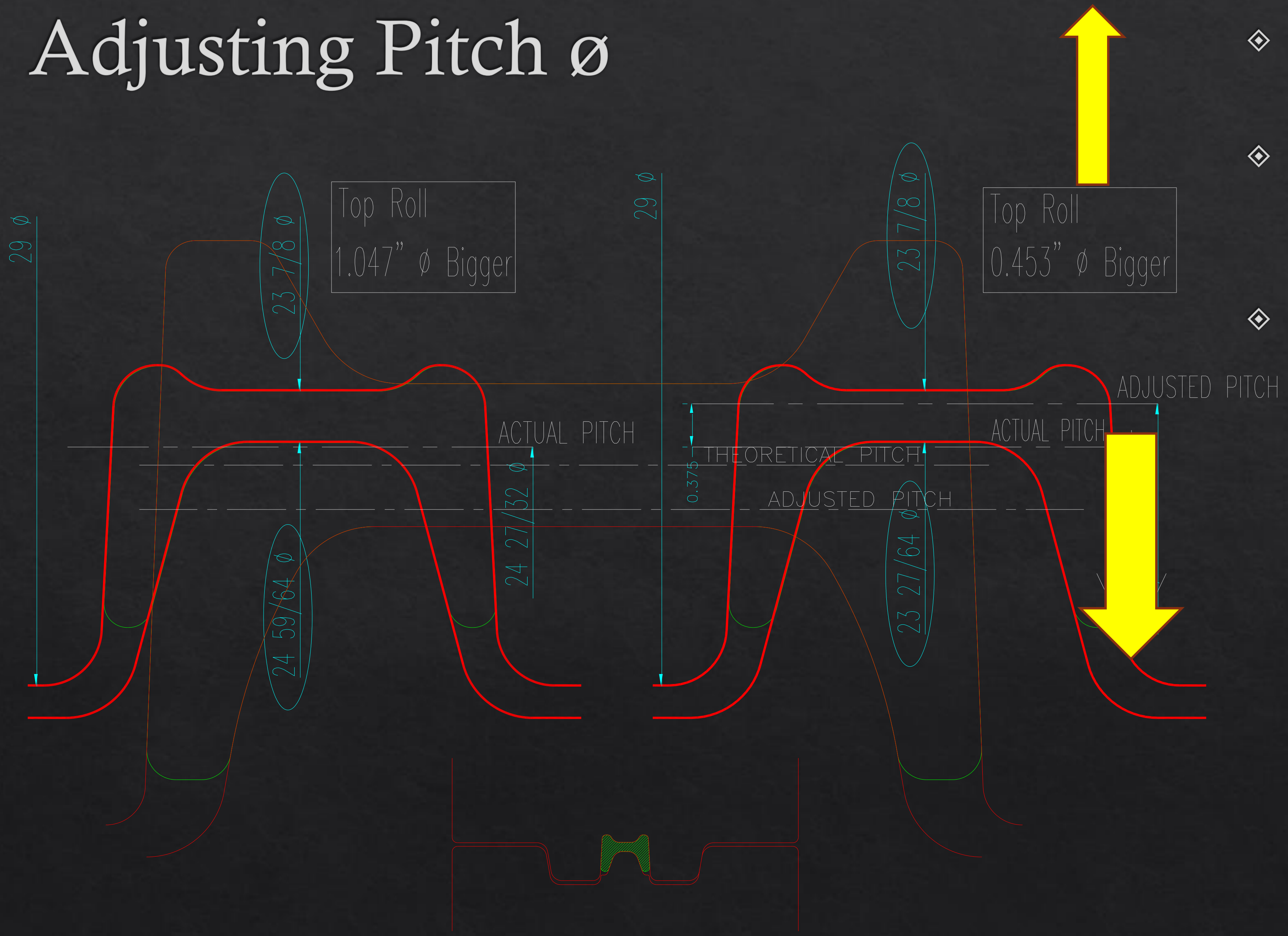


If set equal for heavy weight, insufficient for lightweights



If common passes for various weights use light weight to set pitch

Adjusting Pitch ø



- Bar will want to collar roll with greatest surface contact
- Counteract collar tendency by adjusting pitch dia. toward tendency
- Wide channel can be adjusted opposite to balance wiping tendency from dissimilar roll speeds

Thank You

Any Questions or Comments?