Kinematics & Dynamics of Linkages

Lecture 8: Chains

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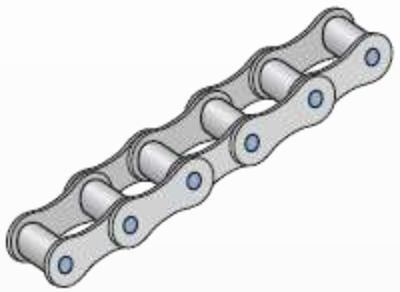
Chain Drives

- Less expensive than gear drives
- No slippage as in belts
- Flexible shaft distances (unlike gears)
- Require less adjustment than belts
- More effective at lower speeds than belts
- Longer service life than belts
- Requires little adjustment
- Noisy and needs a lot of lubrication

http://legmannews.com/global-industrial-roller-chain-drives-market-2017-iwis-renold-rexnord-tsubakimoto-chain-diamond-chain-company-did-dong-bo-chain-dbc/

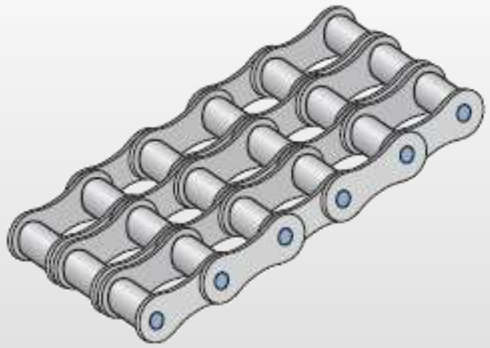
Types of chains

Roller chain: most common, provides quiet and efficient operation but must be lubricated



(a) Roller chain

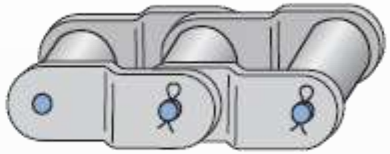
Multiple-strand roller chain: multiple standard parallel roller chains, increases power capacity.



(b) Multiple-strand roller chain

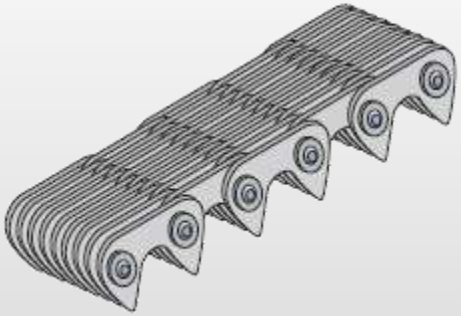
Types of chains

Offset sidebar roller chain: less expensive, less power capability, withstand dirt and contaminants.



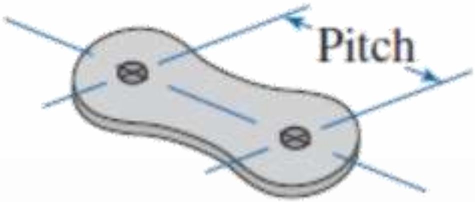
(c) Offset sidebar roller chain

Inverted tooth silent chain: most expensive, efficient for high speed, smooth, quiet. Required lubrication



(d) Silent chain

Roller chain pitch



- The design and dimensions of power transmission chains is maintained my ANSI standard B29-1.
- Roller chains are classified by a pitch, *p*, which is the distance between the pins that connect the adjacent links
- Roller chains have a size designation ranging from 25 to 240.
- Size designation refers to the pitch of the chain in 1/80th of an inch (e.g. 120 chain has a pitch of 120/180 = 1.5 inch)

Multistrand Chains

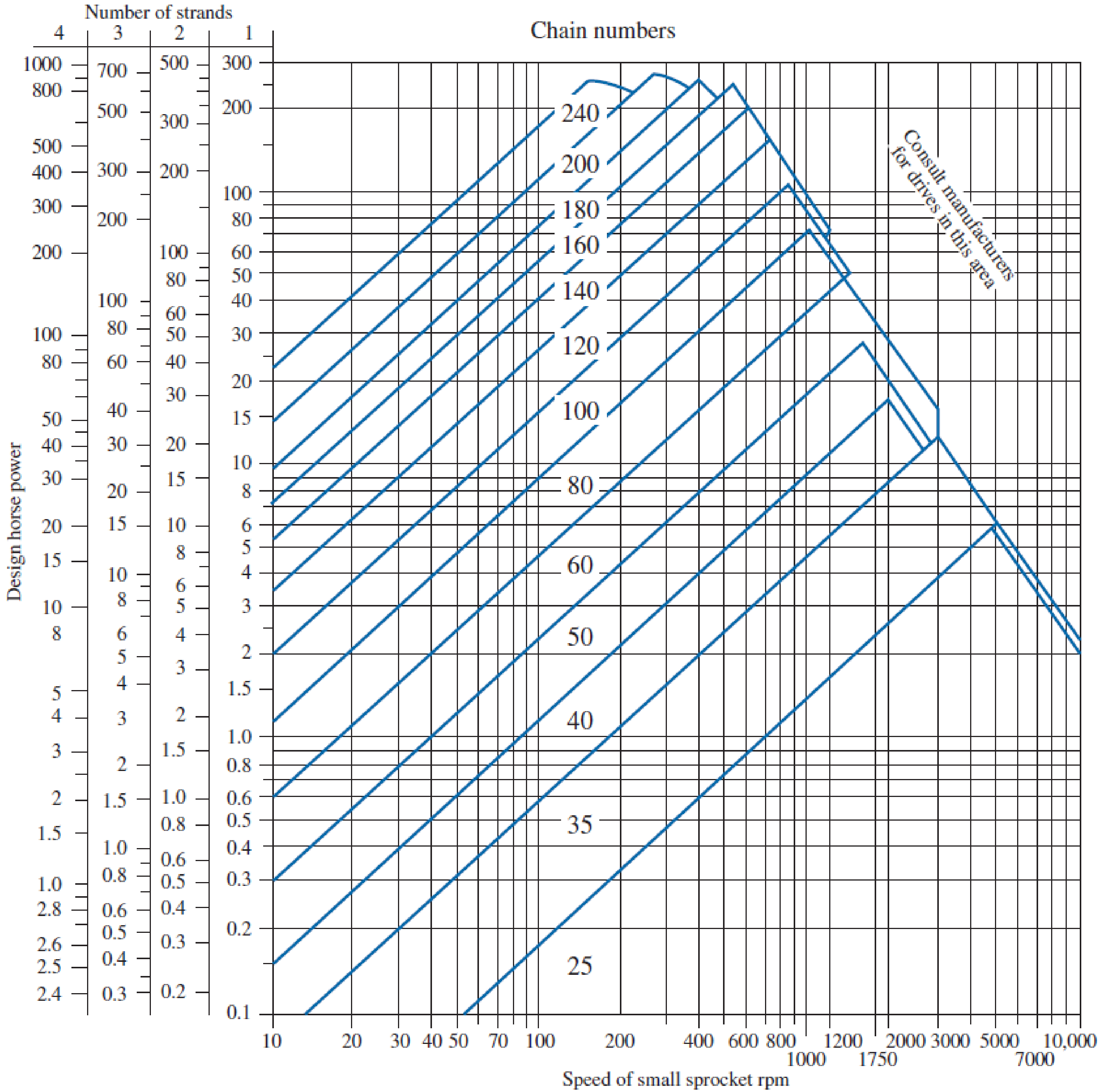
- Multiple-strand chains can be used to increase the amount of power transmitted by the chain drive according to equation:

$$\text{Power per chain} = \frac{\text{total power transmitted}}{\text{multistrand factor}} \qquad (11.9)$$

- A multistrand factor has been experimentally determined and is tabulated in Table 11.4.wer transmitted through each chain.

TABLE 11.4 Multistrand Factor

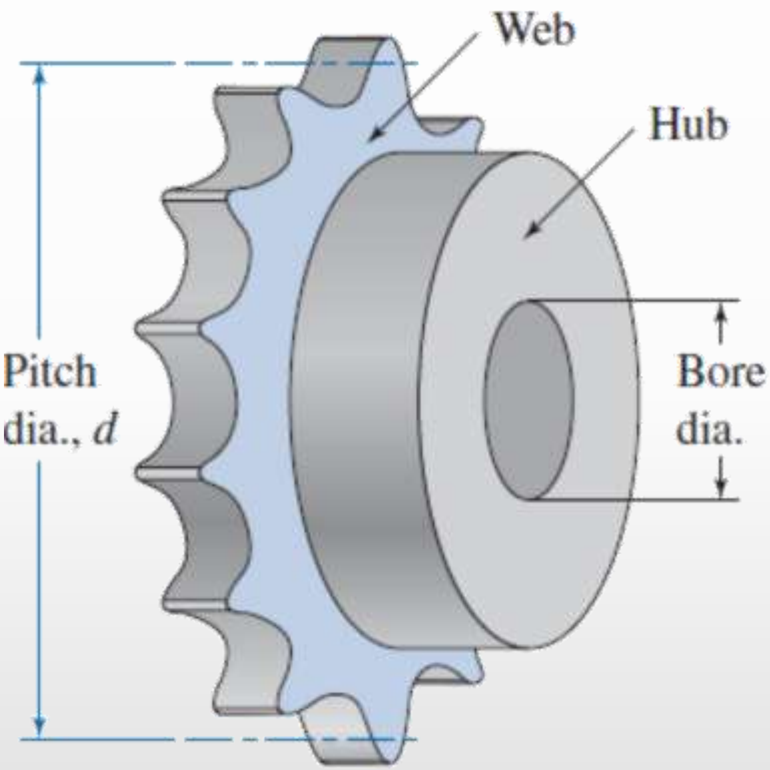
Number of Roller Chain Strands	2	3	4	5	6	8	10
Multistrand Factor	1.7	2.5	3.3	3.9	4.6	6.2	7.5



Number of strands
4
3
2
1
Chain numbers
240
200
180
160
140
120
100
80
60
50
40
35
25
Consult manufacturers for drives in this area
Design horse power
Speed of small sprocket rpm
10
20
30
40
50
70
100
200
400
600
800
1000
1200
1750
2000
3000
5000
7000
10,000

Sprockets

- Toothed wheels that connect to the shaft and mate with the chain
- The teeth on the sprocket are designed with geometry to conform to the chain pin and link
- Sprockets are commonly referenced by the corresponding chain size and the number of teeth.



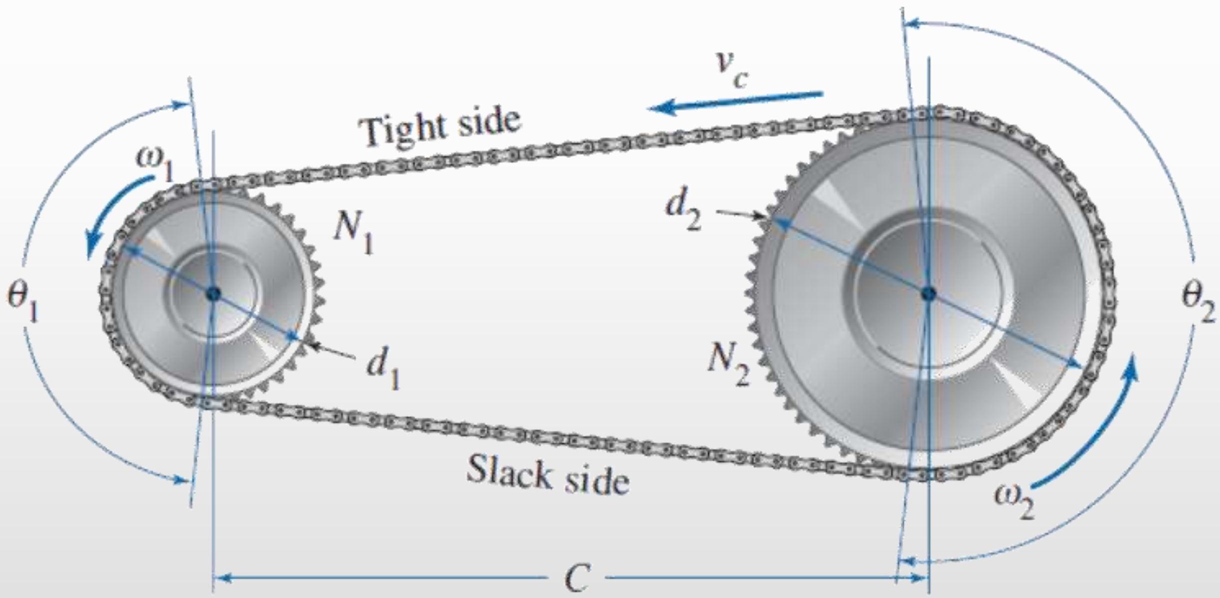
Commercially available sprockets

TABLE 11.5 Commercially Available Single-Strand Sprockets

Chain Size	Number of Teeth on the Sprocket
25	8 through 30, 32, 34, 35, 36, 40, 42, 45, 48, 54, 60, 64, 65, 70, 72, 76, 80, 84, 90, 95, 96, 102, 112, 120
35	4 through 45, 48, 52, 54, 60, 64, 65, 68, 70, 72, 76, 80, 84, 90, 95, 96, 102, 112, 120
40	8 through 60, 64, 65, 68, 70, 72, 76, 80, 84, 90, 95, 96, 102, 112, 120
50	8 through 60, 64, 65, 68, 70, 72, 76, 80, 84, 90, 95, 96, 102, 112, 120
60	8 through 60, 62, 63, 64, 65, 66, 67, 68, 70, 72, 76, 80, 84, 90, 95, 96, 102, 112, 120
80	8 through 60, 64, 65, 68, 70, 72, 76, 78, 80, 84, 90, 95, 96, 102, 112, 120
100	8 through 60, 64, 65, 67, 68, 70, 72, 74, 76, 80, 84, 90, 95, 96, 102, 112, 120
120	9 through 45, 46, 48, 50, 52, 54, 55, 57, 60, 64, 65, 67, 68, 70, 72, 76, 80, 84, 90, 96, 102, 112, 120
140	9 through 28, 30, 31, 32, 33, 34, 35, 36, 37, 39, 40, 42, 43, 45, 48, 54, 60, 64, 65, 68, 70, 72, 76, 80, 84, 96
160	8 through 30, 32 through 36, 38, 40, 45, 46, 50, 52, 53, 54, 56, 57, 60, 62, 63, 64, 65, 66, 68, 70, 72, 73, 80, 84, 96
180	13 through 25, 28, 35, 39, 40, 45, 54, 60
200	9 through 30, 32, 33, 35, 36, 39, 40, 42, 44, 45, 48, 50, 51, 54, 56, 58, 59, 60, 63, 64, 65, 68, 70, 72
240	9 through 30, 32, 35, 36, 40, 44, 45, 48, 52, 54, 60

Chain drive geometry

Chain drive geometry is identical to that of the belt drive



Number of sprocket teeth

- It is generally recommended that sprockets have at least 17 teeth, unless they operate at speeds under 100 rpm. The larger sprocket should normally have no more than 120 teeth.
- The *pitch diameter, d,* of the sprocket is measured to the point on the teeth where the center of the chain rides which is slightly smaller than the outside diameter. The pitch diameter of a sprocket with *N* teeth for a chain with a pitch of *p* is given by

$$d = \frac{p}{\sin\left(180^\circ / N\right)} \qquad (11.10)$$

Center distance and chain length

- The *center distance, C,* should be in the following range:

$$30p < C < 50p$$

- The *chain length* is the total length of the chain and must be an integral multiple of the pitch. The *chain length, L*, expressed in number of links, or pitches, can be computed as:

$$L = \frac{2C}{p} + \frac{(N_2 + N_1)}{2} + \left\{ \frac{p(N_2 - N_1)^2}{4\pi^2 C} \right\} \quad (11.11)$$

Center distance given chain length

The center distance for a given chain length can be computed as:

$$C = \frac{p}{4}\left[L - \frac{(N_2 + N_1)}{2} + \sqrt{\left\{ L - \frac{(N_2 + N_1)}{2} \right\}^2 - \frac{8(N_2 - N_1)^2}{4\pi^2}} \right] \quad (11.12)$$

Angle of contact

The *angle of contact* is a measure of the angular engagement of the chain on each sprocket

$$\theta_1 = 180^\circ - 2\sin^{-1}\left\{\frac{p(N_2 - N_1)}{2C}\right\} \quad (11.13)$$

$$\theta_2 = 180^\circ + 2\sin^{-1}\left\{\frac{p(N_2 - N_1)}{2C}\right\} \quad (11.14)$$

Chain manufacturers suggest keeping the angle of contact greater than 120º when possible.

Chain drive kinematics

- The *velocity ratio, VR,* is defined as the angular speed of the driver sprocket (sprocket 1) divided by the angular speed of the driven sprocket (sprocket 2):

$$VR = \frac{\omega_{driver}}{\omega_{driven}} = \frac{\omega_1}{\omega_2} = \frac{d_2}{d_1} = \frac{N_2}{N_1} \quad (11.15)$$

- The *linear velocity, v_c,* of the chain, or chain speed, is defined as:

$$v_c = \frac{d_1}{2}\omega_1 = \frac{d_2}{2}\omega_2 \quad (11.16)$$

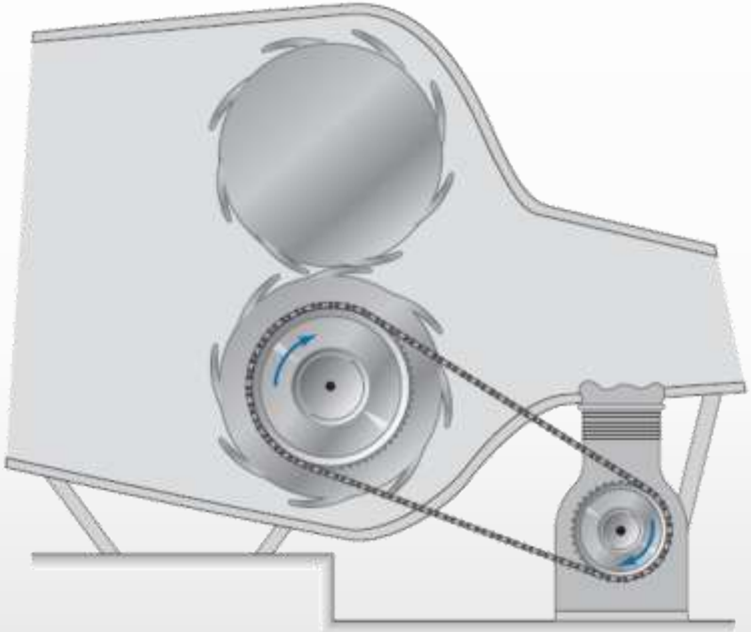
Chain lubrication

Recommended lubrication methods are primarily dictated by the speed of the chain:

- **Low speed** (v_c < 650 fpm): manual lubrication, where the oil is periodically applied to the links of the chain.
- **Moderate speed** (650 < v_c < 1500 fpm): bath lubrication, where the lowest part of the chain dips into a bath of oil.
- **High speed** (1500 fpm < v_c): oil stream lubrication, where a pump delivers a continuous stream onto the chain.

Example

A single-strand roller chain drive connects a 10-hp engine to a lawn waste shredder.
As the engine operates at 1200 rpm, the shredding teeth should rotate at 240 rpm.
The drive sprocket has 18 teeth. Determine an appropriate pitch for the chain, the number of teeth on the driven sprocket, the pitch diameters of both sprockets, and the chain speed. Also indicate the number of links in a suitable chain and specify the required center distance.



Example solution

1. Select an Appropriate Chain Pitch:

With a 10-hp engine driving a sprocket at 1200 rpm, Figure 11.10 specifies that a 40-pitch, single-strand chain is appropriate.

2. Determine the Number of Teeth on the Driven Sprocket

By rewriting equation (11.15), the number of teeth needed on the driven sprocket can be determined.

$$N_2 = N_1\left(\frac{\omega_1}{\omega_2}\right) = 18\left\{\frac{1200\ rpm}{240\ rpm}\right\} = 90\ teeth$$

Example solution

3. Determine the Pitch Diameter of the Sprockets

A No. 40 roller chain has a pitch of

$$p = \frac{40}{80} = 0.5\ in$$

From equation (11.10), the pitch diameters of the sprockets are

$$d_1 = \frac{p}{\sin\left(\frac{180^\circ}{N_1}\right)} = \frac{0.5}{\sin\left(\frac{180^\circ}{18\ teeth}\right)} = 2.88\ in$$

$$d_2 = \frac{p}{\sin\left(\frac{180^\circ}{N_2}\right)} = \frac{0.5}{\sin\left(\frac{180^\circ}{90\ teeth}\right)} = 14.33\ in$$

Example solution

4. Calculate the Chain Speed

The chain speed can be calculated from equation (11.16).

$$\omega_1 = 1200\ rev/\min\left(\frac{2\pi}{1\ rev}\right) = 10{,}838\ rad/\min$$

$$v_c = \frac{d_1}{2}\omega_1 = \left(\frac{2.88\,in}{2}\right) 10{,}833\,rad/\min = 15{,}603\ in/\min = 1300\ fpm$$

With a chain speed of 1300 fpm, a bath lubrication system for the chain is desired

Example solution

5. Determine an Appropriate Center Distance

The suggested center distance for a chain drive is

$$30p < C < 50p$$

$$15\ in < C < 25\ in$$

A mid-value of 20 in. is tentatively selected. Substituting into equation (11.11) gives

$$L = \frac{2(20)}{0.5} + \frac{(90+18)}{2} + \left\{ \frac{0.5(90-18)^2}{4\pi^2(20)} \right\} = 137.28\ links$$

Example solution

5. Determine an Appropriate Center Distance

An even 138 links will be specified. The corresponding, actual center distance is computed from equation (11.12).

$$C = \frac{p}{4}\left[L - \frac{\left(N_2 + N_1\right)}{2} + \sqrt{\left\{ L - \frac{\left(N_2 + N_1\right)}{2} \right\}^2 - \frac{8\left(N_2 - N_1\right)^2}{4\pi^2}} \right]$$

$$C = \frac{0.5}{4}\left[138 - \frac{\left(90 + 18\right)}{2} + \sqrt{\left(138 - \frac{90 + 18}{2} \right)^2 - \frac{8\left(90 - 18\right)^2}{4^{p^2}}} \right] = 20.187\ in$$