INSTRUCTIONS FOR USE OF SLIDE RULE

TYPICAL EXAMPLE ILLUSTRATING THE METHOD OF USING THE SLIDE RULE FOR CALCULATING ROLL SEPARATING FORCE AND TORQUE

The calculation procedure to be followed is given on the face of the stock in the centre at the left hand end. The vertical lines between the symbols indicate that the figure represented by the symbol on the right hand side of the vertical line should be under the cursor line which is set to the preceding symbol. The arrow head pointing to the right indicates that the cursor should be moved to the figure represented by the symbol pointed to. The exclamation mark given at the end of the first line indicates that the top slide should not be moved until the Z_2 scale has been used, during the second chain of calculations.

Symbols underlined indicate that these should be read.

The symbols used in the chain of calculations are interpreted as follows :—

V	represents strip velocity in ft. per minute at the delivery speed of the Mill.
h_2	represents the outgoing thickness of the material in inches.
d_1	represents roll diameter in inches on the first scale.
M_1	represents the ratio between h_1 and h_2.
X	represents the viscosity constant for the material.
Y	represents the total of the viscosity constant, plus the carbon content, plus the manganese content, plus 0·3 of the chrome content of the material being rolled.
tfV_1	represents the strip temperature in degrees F. Ekulund Scale.
tfV_2	represents the strip temperature in degrees F. on the Hogiljanskij Experimental Scale.
d_2	represents the roll diameter in inches on the second scale.
tff	represents the strip temperature in degrees F. for either rough or smooth rolls.
M_2	represents the ratio between h_1 and h_2 on the second scale.
h_1	represents the ingoing thickness of the material in inches.
Z_1 & Z_2	are constant.
δ	is the draft.
b	represents the width of strip in inches.
P	represents the roll separating force in tons.
T	represents the torque required in lbs./ft. × 1000.

TYPICAL EXAMPLE :

On a 2-High Mill having rolls of chilled cast iron with a diameter of D=20", a steel strip having a width of 24" is rolled down in one pass from an initial thickness h_1 of ·236" to a final thickness of h_2 of ·1575"; the rolling load P and the rolling torque T will be calculated on the assumption that the rolling speed V is 960 ft. per minute. The temperature tff of the steel being rolled is 1700°F and its composition is :

Carbon 0·1%
Manganese 0·5%
Chrome 0·0%

The given data are summarised below :

V 960 ft./min.	D =20"
h_2 =·1575	b =24"
δ =·236—·1575=·0785	tf =1700°F.
$M = \frac{h_1}{h_2} = \frac{·236}{·1575} = 1·5$	C+Mn+0·3 Cr= 0·1+0·5+0=0·6

Material of rolls—chilled cast iron.

CALCULATION PROCEDURE

1st chain of calculation : $V/h_2 \rightarrow d_1/M_1 \rightarrow \phi/\underline{X}$; X+C+Mn+0·3 Cr =Y; Y/tfV_1!

2nd chain of calculation : $d_2/h_2 \rightarrow tff/M_2\underline{Z_1}$.

3rd chain of calculation : $Z_1/d_1 \rightarrow \delta/\oplus \rightarrow b/\underline{P}$ $P/d_1-\delta/\underline{T}$.

PROCEDURE

1st Chain

I. With the cursor line set at the strip velocity on the V scale (bottom part of stock to the left), move the bottom slide to bring the h_2-scale (bottom edge of bottom slide) under the cursor line.

The expression V/h_2 of the calculation procedure corresponds to these operations. In other words—do as you are accustomed to do when dividing " V " by " h_2 " by means of an ordinary slide rule.

II. Without moving the bottom slide, set the cursor line to 20" on the d_1 scale (top edge of bottom slide to the right) and move the top slide until 1·5 on the M_1 scale (top edge of top slide to the left) is under the cursor line.

This operation is represented in the calculation by $\rightarrow d_1/M_1$: The horizontal arrow → means move the cursor to the next scale or (start a new " division ", bearing in mind the procedure when using an ordinary slide rule for this purpose).

III. Without moving the top slide, move the cursor line to the mark ϕ of the M_1 scale and on the scale X (top part of stock, top row of figures) read the figure under the cursor line. In the example $\underline{X}$=0·81.

This operation is represented in the procedure thus :

$\rightarrow \phi/\underline{X}$

Underlining X indicates : read this figure.

V. Add this figure X=0·81 to the given amount of C+Mn+0·3 Cr. (0·6 giving 0·81+0·6)=1·41=Y.

V. Set the cursor line at Y (1·41 calculated above) on the Y scale (top edge of middle part of stock on the left) and move the top slide to bring 1700°F on the tfV_2 scale (top edge of top slide on the left) under the cursor line.

Regarding the tfV_2 scale—see remarks at foot of these notes.

The above operation is represented in the procedure by Y/tfV_2 ! (The exclamation mark ! is merely to remind the user not to move the top slide until reference is made to the Z_2 scale later in the calculations).

This completes the first chain of calculations. The top slide must remain stationary in the above position until the start of the third chain of calculations, and its position fixes the result of this first chain, and this result will be used in connection with the result of the second chain of calculations.

2nd Chain

I. The cursor line is set at the roll diameter of 20" on the d_2 scale (bottom part of stock on the right) and the bottom slide moved to bring the outgoing thickness h_2=·1575 on the h_2 scale (bottom edge of bottom slide) under the cursor line.

This operation is represented in the procedure by d_2/h_2.

II. Without moving the bottom slide, put the cursor line on 1700°F on the tf scale for smooth rolls (in the middle of the bottom slide to the left). This scale is calculated for=(1·05—0·0005t)×0·8.

When rolling with non-polished cast steel rolls, the other scale for rough rolls must be used. (Top edge of bottom slide to the left), this latter scale being calculated for=1·05—0·0005t.

Without moving the cursor, notice the point of intersection of the cursor line and the horizontal line M_2 (of the system of Z_1 curves) which bears the number M_2=1·5. (These figures are given on the extreme right in the centre of the stock).

Estimate the value of Z_1 corresponding to the curve through this point of intersection. In the example Z_1=2·48.

In the scheme this operation is represented by→ tf/M_2 $\underline{Z_1}$.

The underlined symbol Z_1 means—Read the figure for Z_1=2·48.

3rd Chain

This chain is a continuation of the interrupted 1st chain.

I. Set the cursor line to the value 2·48 on the Z_2 scale (bottom part of top slide to the right).

Since the top slide was not moved in the second chain of calculations its position gives the final result of the first chain of calculations, and in this way it is not necessary to read off the result of the first chain of calculations.

Move the bottom slide so as to bring the roll diameter 20" on the d_1 scale under the cursor line.

This operation is represented in the procedure by →Z_2/d_1.

II. Without moving the bottom slide, set the cursor line to the draft ·0785 on the scale δ (bottom edge of bottom slide) and move the top slide to bring the mark ⌖ of the b scale (top edge of top slide on the right) under the cursor line.

This operation is represented in the procedure by→ δ/⌖.

III. Without moving the top slide, set the cursor line at 24" on the b scale (top edge of top slide on the right), and on the P scale (top part of stock, bottom row of figures), read the separating force P, which in this example is 452 tons.

In the procedure, this calculation is represented by → b/P. The rolling load thus found is 452 tons. The rolling torque T is then calculated from the rolling load P thus :

IV. Without moving the cursor, which is now set at P=452 tons, move the bottom slide to bring the roll diameter 20" of the d_1 scale, under the cursor line. In the procedure this is shown P/d_1.

V. Without moving the bottom slide set the cursor line to the draft ·0785 on the δ scale. The rolling torque can now be read on the T scale (bottom scale on the centre of stock) under the cursor life, and in this example reads 75000 lbs./ft.

REMARKS :

(1) On the top slide on the right are two scales for the rolling temperature, tfV_1 Ekel and tfV_2 Experiment.

The scale tfV_1 is used to calculate the rolling load when employing the viscosity expression given by Ekelund.

Coefficient of viscosity=0·01 (14—0·01t) Kg.sec./mm²

Static yield stress=(14—0·01t) (1·4+C+Mn+0·3 Cr) Kg./mm²

The second scale tfV_2 is used in the calculation of the roll separating force with the corrected value of viscosity, which is based on the experiments carried out by Anotol Mogiljanskij in the Rolling Mills of Vitkovice.

$$=0{\cdot}01\ (18-0{\cdot}012t)\ \frac{Kg.sec.}{mm^2}$$

$$=(18-0{\cdot}012t)\ (1{\cdot}4+C+Mn+0{\cdot}3\ Cr)\ Kg/mm^2$$

(This latter scale should be used for calculations of rolling load for the rolling of strip from slabs).

(2) For strips with a width of less than 2", for example : b=$1\frac{1}{2}$", calculate with 10 times the width of strip, i.e. b=15". One then obtains 10 times the required rolling load and torque.