A critical note on several comments on analysis of cold strip rolling

technische hogeschool eindhoven
laboratorium voor mechanische technologie en werkplaatstechniek

rapport van de sectie: Werkplaatstechniek

codering: P6a P7a

titel:

A critical note on several comments on analyses of cold strip rolling.

auteur(s):

ir. E. Mot.

trefwoord: plasticiteit

sectieleider: —

hoogleraar: prof. dr. P.C. Veenstra

samenvatting

Dit rapport bewijst dat de theorieën van Avitzur enerzijds en Bland en Ford anderzijds op het gebied van plaatwalsen niet wezenlijk van elkaar verschillen.
Op grond hiervan is er aanleiding de waarde van de kritiek van Ford en anderen op het werk van Avitzur sterk te relativeren.

prognose

datum: 11-3-'68

aantal blz. 4

geschikt voor publicatie in:
Jrn. of Eng. for Ind.
ASME
Series B.

Journal of Engineering for Industry

Transactions of the ASME - Series B.

Letter to the Editor.

A critical note on several comments on analyses of cold strip rolling.

E. Mot*

A number of years ago, Mr. Avitzur published several articles on cold strip rolling [1, 2, 3]. These publications caused unusually sharp reactions from some other specialists on the subject, e.g.

...."Dr. J.M. Alexander wrote to say that he thought the author's whole approach to the problem of cold strip rolling was dangerously misleading".[1]

...."The writers are mistified as to why these efforts are necessary when an adequate theory for all normal cold rolling problems already exists". (comment of J.M. Alexander and H. Ford), [3].

As to the second comment, Mr. Avitzur replied that he had drawn several conclusions that had not been drawn before. All authors concerned, however, have completely overlooked the fact that Mr. Avitzur's theories could for a great deal also be derived from the existing theory of D.R. Bland and H. Ford [4], so that a further development of the latter theory would irrevocably have led to identical conclusions.
In reference [4], the authors use an approximate equilibrium approach and derive the following expressions for the normal pressure curve

$$s^{+} = \frac{kh}{h_o}\left(1 - \frac{\sigma_o}{k_o}\right) e^{\mu H} \qquad (1)$$

$$s^{-} = \frac{kh}{h_i}\left(1 - \frac{\sigma_i}{k_i}\right) e^{\mu (H_i - H)} \qquad (2)$$

* Department of Production Engineering,
Technological University Eindhoven, Netherlands.

in which

$$H = 2\sqrt{\frac{R'}{h_o}}\ \arctan\left(\sqrt{\frac{R'}{h_o}}\cdot\Phi\right) \tag{3}$$

The neutral point is found by the requirement

$$s_n^{+} = s_n^{-} \tag{4}$$

from which

$$H_n = \frac{H_i}{2} - \frac{1}{2\mu}\ln\left\{\frac{h_i}{h_o}\left(\frac{1-\frac{\sigma_o}{k_o}}{1-\frac{\sigma_i}{k_i}}\right)\right\} \tag{5}$$

I take the liberty to extend this consideration and to introduce a perfectly logical hypothesis:

it.) Maximum reduction takes place if all friction force is used to pull the strip in between the rolls.

This can be formulated by

$$H_n = 0. \tag{6}$$

Using (5) and (3), we derive from (6):

$$\mu = \tfrac{1}{2}\sqrt{\frac{h_o}{R'}}\cdot\frac{\ln\left\{\frac{h_i}{h_o}\left(\frac{1-\frac{\sigma_o}{k_o}}{1-\frac{\sigma_i}{k_i}}\right)\right\}}{\arctan\left(\sqrt{\frac{h_i}{h_o}-1}\right)} \tag{7}$$

If no front or back tensions are applied, we find

$$\mu = \tfrac{1}{2}\sqrt{\frac{h_o}{R'}}\cdot\frac{\ln\frac{h_i}{h_o}}{\arctan\left(\sqrt{\frac{h_i}{h_o}-1}\right)} \tag{8}$$

This is exactly formula (7) of ref. [1], which, however, was derived from a totally different consideration, viz. an energy approach.

For a given value of μ, we may also derive maximum and minimum possible reductions from (5) and (6) by successive approximations and find results which are similar to those mentioned in refs. [1] and [2].

The theory of Bland and Ford is generally recognised as a valuable contribution to the mechanics of metalworking processes and is e.g. quoted by Johnson and Mellor [5]. Therefore, it seems hardly justifiable to classify a theory which differs in approach but not in ultimate result as "dangerously misleading".

The second comment quoted seems correct to this extent that all conclusions of Avitzur could have been drawn from earlier theories. It should be added, though, that this has not been done. However, as for ref. [3], the importance is far beyond the scope of solving a strip rolling problem. It is a demonstration of a technical application of the important lower upper-bound theorem, and up to now only few scientists have been able to use this theorem successfully in this field. In my opinion, further application of extremum principles in plasticity mechanics will prove to be very useful and give a better insight in many processes which are nowadays considered to be insoluble.

Therefore - as far as I am concerned - Mr. Avitzur is congratulated with his work.

Nomendature (similar to ref. [4])

h	thickness of strip
k	maximum shear stress
s	normal roll pressure
R'	radius of deformed are of contact
Φ	angular co-ordinate, radians
μ	coefficient of friction between roll surface and material.
σ	tensile stress (front or back pull)

Suffixes:

i	entry
o	exit
n	neutral point
+	between o and n
-	between n and i

References:

[1] B. Avitzur, Maximum reduction in cold strip rolling, Proc.Inst. Mech. Engrs., Vol. 174 No. 32, 1960, p.865-884.

[2] B. Avitzur, Power analysis of cold strip rolling, Jrn. of Eng. for Ind., Trans. ASME-B, Febr. 1963, p.77-88.

[3] B. Avitzur, An upper bound approach to cold strip rolling, Jrn. of Eng. for Ind., Trans. ASME-B, Febr. 1964, p.31-46.

[4] D.R. Bland & H. Ford, The calculation of roll force and torque in cold strip rolling with tensions, Research on the rolling of strip, a symposium of selected papers, 1948-1958; B.I.S.R.A., p.68-77

[5] W. Johnson & P.B. Mellor, Plasticity for Mechanical Engineers, D. van Nostrand Company Ltd., 1962, p.243-252.