THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI.
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N^0. 2 – 2008, ISSN 1453 – 083X

CONTRIBUTIONS IN THE DOMAIN OF THE CONTACT STRESSES BETWEEN CYLINDERS OF COLD ROLLING

A.D. MAIMON[1], D. BOAZU[2], L. STOICESCU[2]
[1]ARCELOR – Mittal Steel Galati
[2]"Dunărea de Jos" University of Galaţi
email: dboazu@ugal.ro

ABSTRACT

Elasto-plastic contact stresses between working cylinder and support cylinder of cold rolling using FEM are presented in this paper. Pressure and tractions resulted from the rolling process were obtained by using a calculus program and they were used as loads on a working cylinder.

KEYWORDS: cold rolling, elasto-plastic contact stresses, rolling process

1. FEM model of contact between working cylinder (585mm) and support cylinder(1525mm) of cold rolling

For the modelling process COSMOS/M version 2.5 was used. The two cylinders were modelled using PLANE2D (plane strain) elements with 4 nodes and two degrees of freedom per node. 2D model is represented in Fig. 1. A zoom of fin mesh in the vicinity of contact between the two cylinders is presented in Fig. 3 and the mesh in loading zone (load is given by normal and tangential pressure from rolling process) is represented in Fig. 2. The whole model has 14517 nodes and 17101 elements.

One node GAP elements (in 2D node-line contact elements) were used for transmission of stresses and deformations through contact zone.

The two cylinders were considered supported by elastic elements whose rigidity is given by that of the rolling system. Working with GAP elements imposed an incremental loading and so the analysis is static but nonlinear.

The contact between cylinders is a non-conforming contact problem because the extension of contact zone is not known from the beginning.

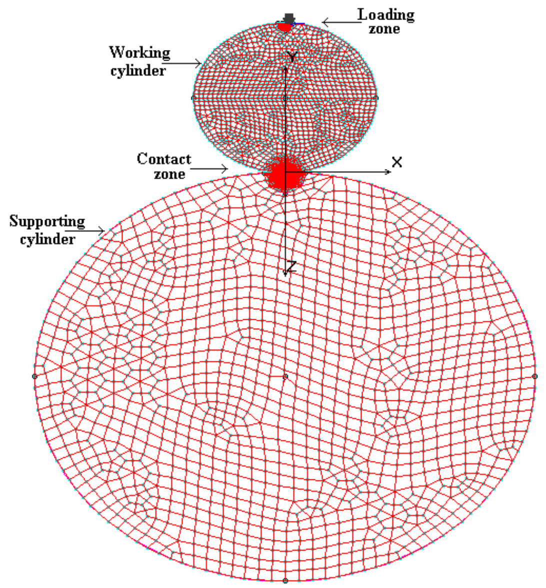

Fig. 1. *FEM model between working cylinder and support cylinder of cold rolling.*

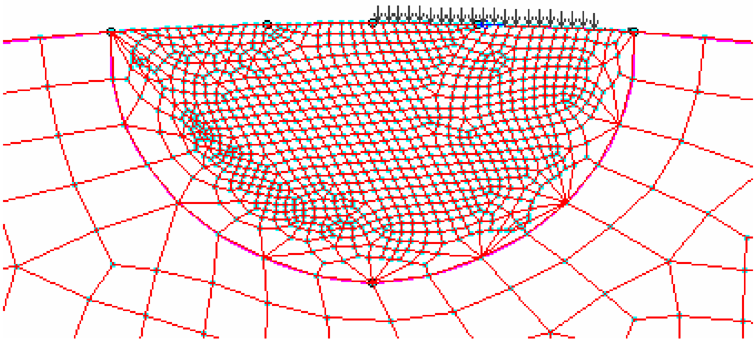

Fig. 2. *Mesh in loading zone of working cylinder*

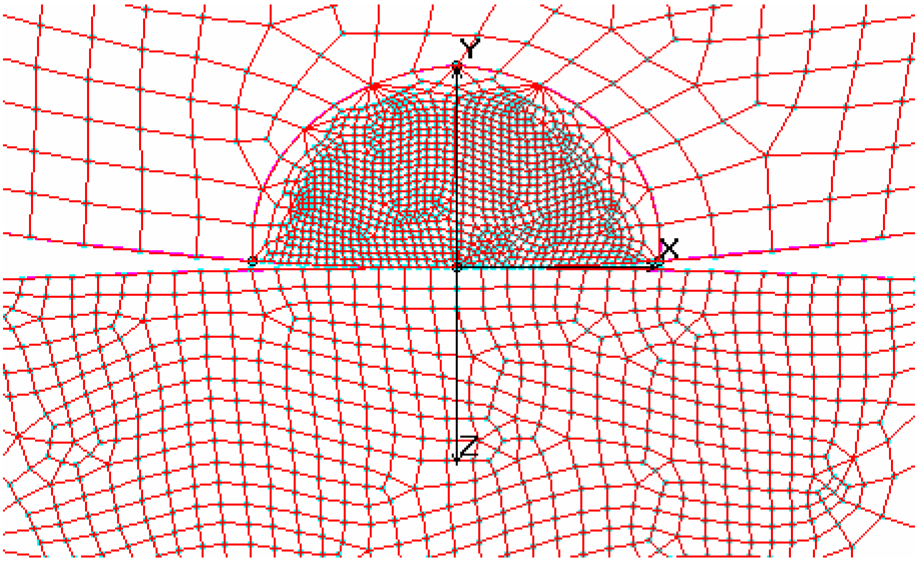

Fig. 3. *Mesh in contact zone between the two cylinders*

2. Material model

The elasto plastic behaviour of material (special steel) of the two cylinders was considered von Mises with isotropic hardening. Principal parameters of material model are: Young modulus E=2.1 10^4 daN/mm^2, Poisson ratio 0.3, yield stress 73 daN/mm^2, and tangent modulus 20daN/mm^2).

3. Studied cases

It was analyzed two cases with the 5 phases of sheet thickness reduction. (17.7%, 20.6%, 24.2%, 20.8, 17.5%). In the first case the friction coefficient was considered μ=0.1 and in the second case friction coefficient was considered μ=0.075. The width of the sheet was considered 1250mm.

The loading conditions for cold rolling were established according to reference [3].

For these analyzed cases the equivalent von Mises stress distribution and principal stresses are represented in Fig. 4-8 (μ=0.1) and Fig. 9-13 (μ=0.075). The extension of contact zone is of 40mm. The contact stain extends to about 40 mm.

The results of nonlinear analysis are given in Table 1 (Case 1 (μ=0.1)) and Table 2 (Case 1 (μ=0.1))-von Mises stresses from contact zone (σech * - for working cylinder) and (σech ** - for supporting cylinder) and principal stresses in the contact zone $\sigma_1, \sigma_2, \sigma_3$. The stress state in the vicinity of contact is 3D. In Tables 1 and 2 principal stresses $\sigma_1 < \sigma_2 < \sigma_3$ are negative values and the biggest one σ_3 is considered the contact stress (Hertzian pressure). The equivalent von Mises stress was evaluated at a distance of 2 mm from contact effective zone, because in the contact zone the components of deviator tensor are unmeaningful.

The influence of friction on loading and contact behaviour was considered by modifying friction coefficient (μ=0.1 for dry friction) and (μ=0.075 for lubrification).

The equivalent von Mises stress is calculated using the formula:

$$VON = \{(1/2)[(\sigma_X - \sigma_Y)^2 + (\sigma_X - \sigma_Z)^2 + (\sigma_Y - \sigma_Z)^2] + 3(\tau^2_{XY} + \tau^2_{XZ} + \tau^2_{YZ})\}^{(1/2)}$$

Or by means of principal stresses:

$$VON = \{(1/2)[(\sigma_1 - \sigma_2)^2 + (\sigma_1 - \sigma_3)^2 + (\sigma_2 - \sigma_3)^2]\}^{(1/2)}$$

Table 1

Case 1 (μ=0.1)	σech * [daN/mm^2]	σech ** [daN/mm^2]	$\sigma_{1,max}$ [daN/mm^2]	$\sigma_{2,max}$ [daN/mm^2]	$\sigma_{3,max}$ [daN/mm^2]
Phase A1	72.95	72.95	79.95	117.97	150.91
Phase A2	73	73	150.4	178.9	215.5
Phase A3	73	73	156.068	184.79	230.258
Phase A4	72.99	72.99	130.989	146.134	200.24
Phase A5	73.563	73.563	253.754	289.142	330.84

Table 2

Case 1 (μ=0.075)	σech * [daN/mm^2]	σech ** [daN/mm^2]	$\sigma_{1,max}$ [daN/mm^2]	$\sigma_{2,max}$ [daN/mm^2]	$\sigma_{3,max}$ [daN/mm^2]
Phase F_A1	72.953	72.953	73.389	108.123	136.507
Phase F_A2	72.890	72.890	81.960	118.186	153.887
Phase F_A3	73.044	73.044	141.576	172.475	217.362
Phase F_A4	72.937	72.937	105.476	129.328	169.797
Phase F_A5	73.036	73.036	167.813	197.075	241.869

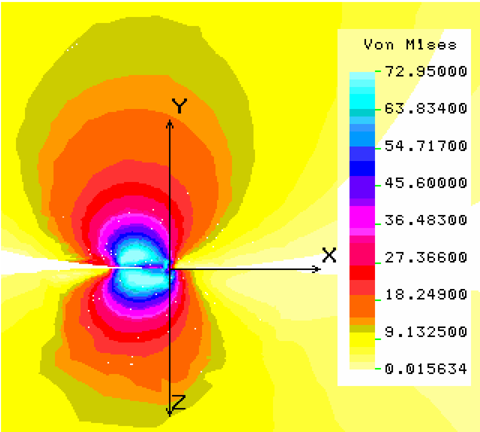

***Fig. 4a.** Case 1 (μ=0.1) Phase A1 von Mises stress*

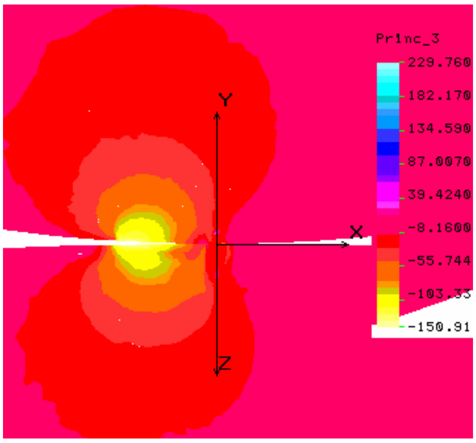

***Fig.4b.** Case 1 (μ=0.1) Phase A1 principal stress σ3*

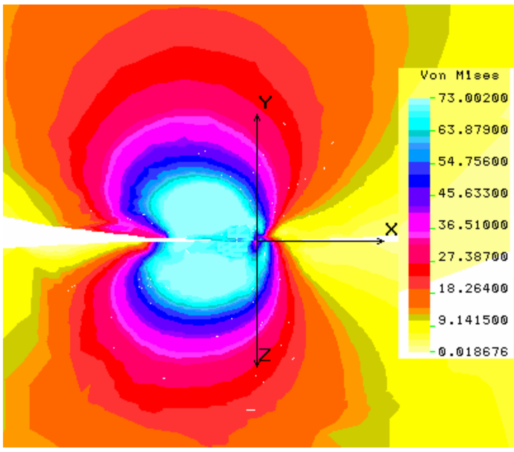

***Fig. 5a.** Case 1 (μ=0.1) Phase A2 von Mises stress*

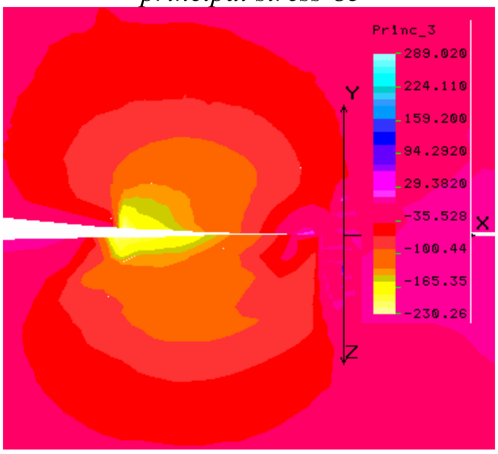

***Fig. 5b.** Case 1 (μ=0.1) Phase A2 principal stress σ3*

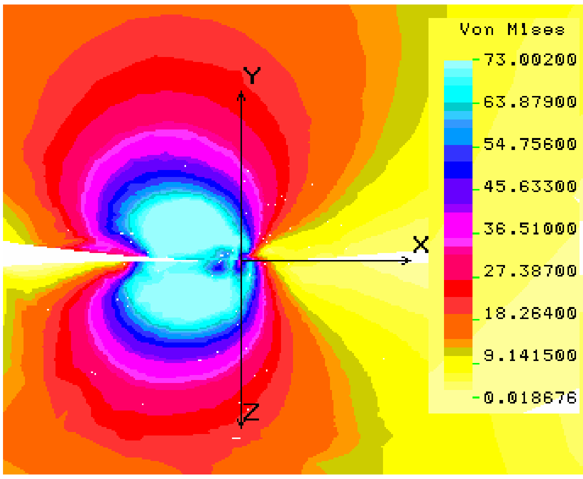

Fig. 6a. *Case 1 (μ=0.1) Phase A3*
von Mises stress

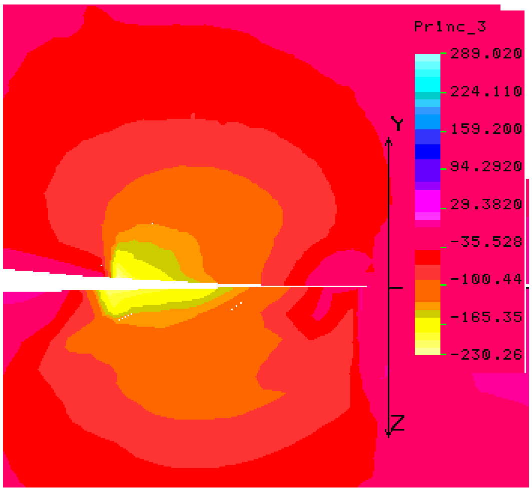

Fig. 6b. *Case 1 (μ=0.1) Phase A3*
principal stress σ3

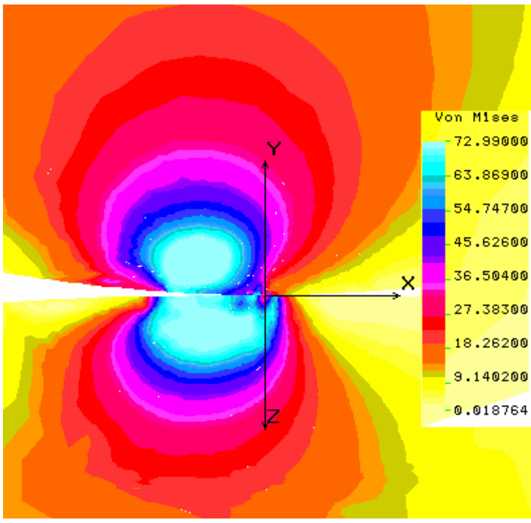

Fig. 7a. *Case 1 (μ=0.1) Phase A4*
principal stress σ3

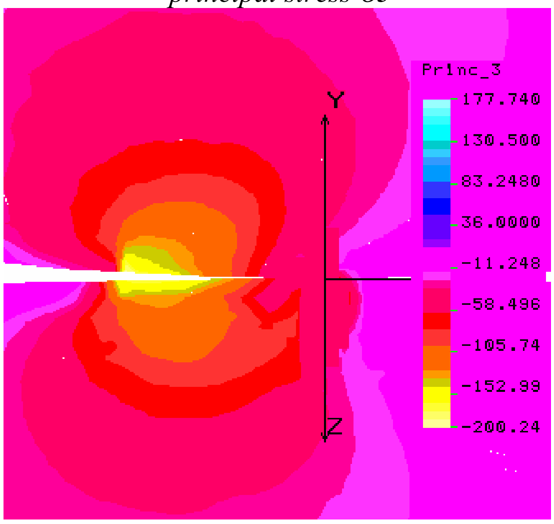

Fig. 7b. *Case 1 (μ=0.1) Phase A4*
principal stress σ3

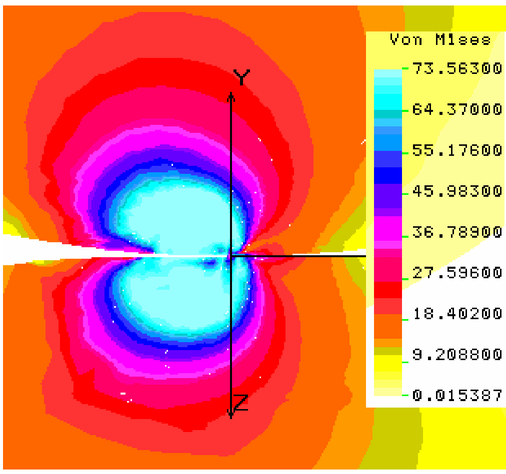

Fig. 8a. *Case 1 (μ=0.1) Phase A5*
principal stress σ3

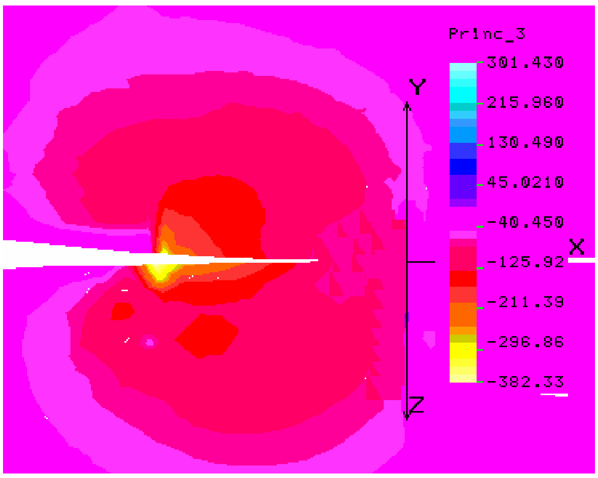

Fig. 8b. *Case 1 (μ=0.1) Phase A5*
principal stress σ3

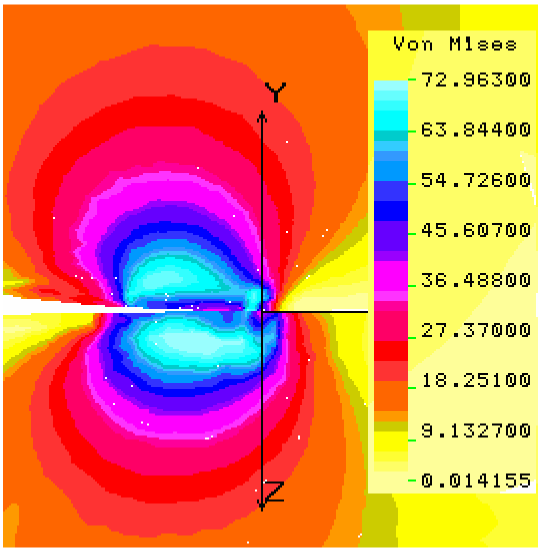

Fig. 9a. *Case 2 (μ=0.075) Phase F_A1 principal stress σ3*

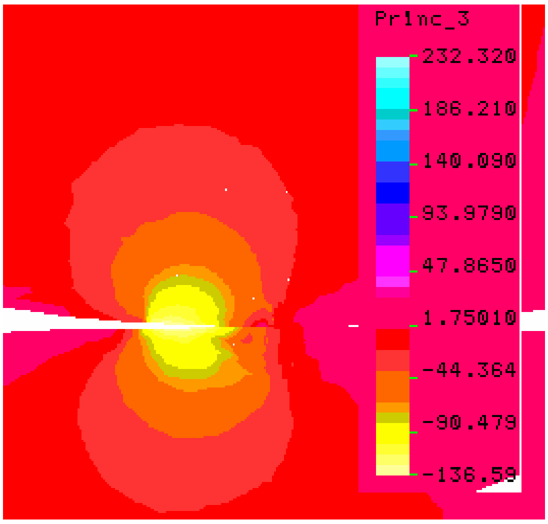

Fig. 9b. *Case 2 (μ=0.075) Phase F_A1 principal stress σ3*

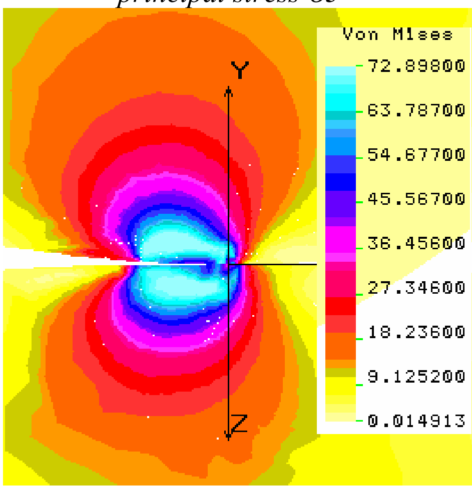

Fig. 10a. *Case 2 (μ=0.075) Phase F_A2 principal stress σ3*

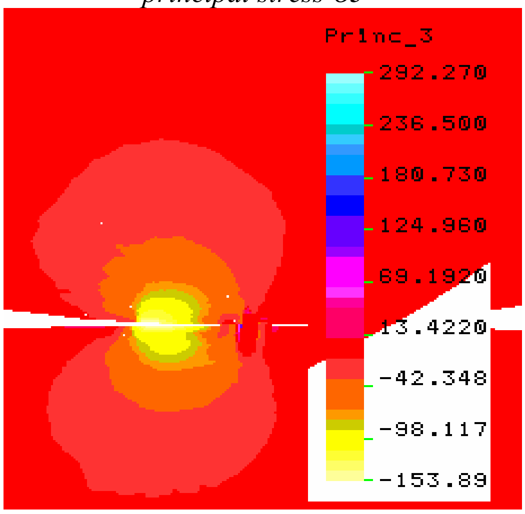

Fig. 10b. *Case 2 (μ=0.075) Phase F_A2 principal stress σ3*

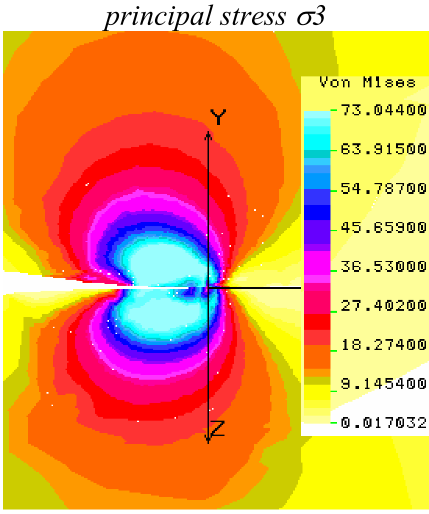

Fig. 11a. *Case 2 (μ=0.075) Phase F_A3 principal stress σ3*

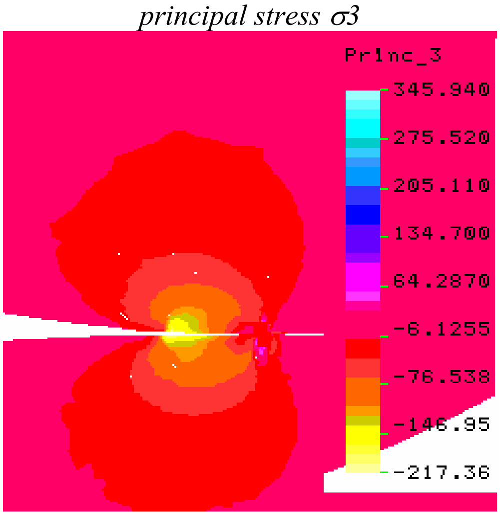

Fig. 11b. *Case 2 (μ=0.075) Phase F_A3 principal stress σ3*

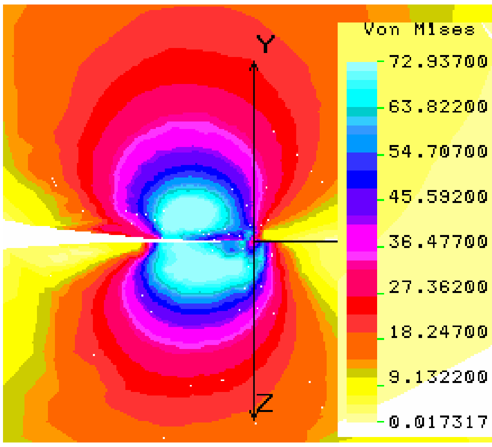

Fig. 12a. *Case 2 (μ=0.075) Phase F_A4 principal stress σ3*

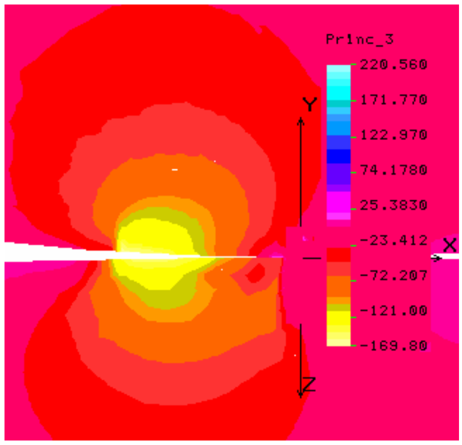

Fig. 12b. *Case 2 (μ=0.075) Phase F_A4 principal stress σ3*

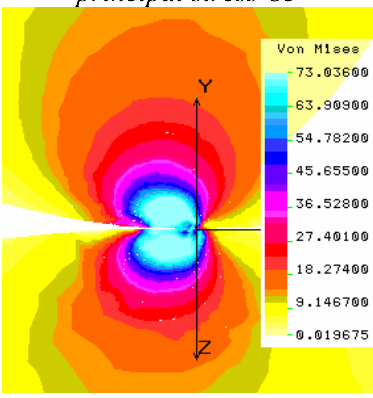

Fig. 13a. *Case 2 (μ=0.075) Phase F_A4 principal stress σ3*

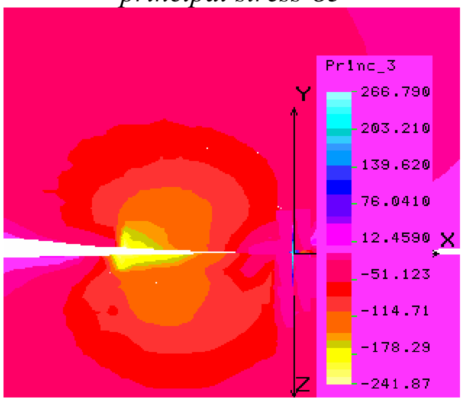

Fig. 13b. *Case 2 (μ=0.075) Phase F_A4 principal stress σ3*

4. Conclusions

From Fig. 14 one can observe that contact stresses are bigger when the rolling process is not lubrificated.

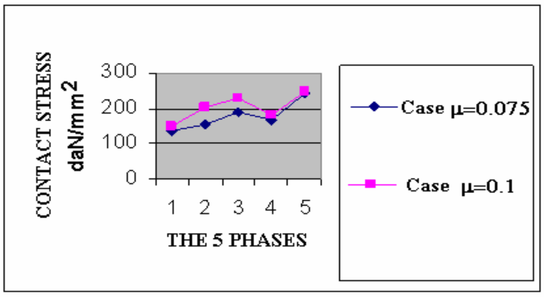

Fig. 14.

For all loading cases there are important plastic zones of elliptic shape. In the worst loading case (Case 1 (μ=0.1) Phase A5 - see table 1) this elliptic region is determined by the two semiaxes of 30mm and 25mm; the eccentricity of this plastic zone in respect to vertical axis of the two cylinders is about 40mm.

References

[1]. Bern A., 1990, *Le laminage a froid*, Symposium franco-roumain, Galati.
[2]. Poloukhine V., 1977, *Simulation mathematique et calcul sur ordinateur des laminoirs a toles*, Edition MIR, Moscou,.
[3]. Stoicescu L., Gavrilescu I., Boazu D., 1995, *Algoritm şi program pentru modelarea laminării la rece*, Asociaţia oamenilor de ştiinţă, filiala Galaţi, Departamentul de Inginerie Tehnologică şi Deformare Plastică, tom 21, octombrie 1995, pg. 123-128.