

Manifested flatness predictions in thin strip cold rolling using a general rolling FEM model

S. Abdelkhalek^{1,2}, H. Zahrouni¹, P. Montmitonnet², N. Legrand³, M. Potier-Ferry¹

¹ LPMM - UMR CNRS 7554 - ISGMP - Université de Paul Verlaine-Metz Ile de Saulcy - 57045 Metz – France, {hamid.zahrouni,michel.potierferry}@univ-metz.fr

² Ecole des Mines de Paris-ParisTech-CEMEF - UMR CNRS 7635 BP 207 - 06904 Sophia-Antipolis - Cedex – France, {sami.abdelkhalek,pierre.montmitonnet}@mines-paristech.fr

³ ArcelorMittal Research Maizières, R&D Industrial Operations BP 30320 - Voie Romaine 57283 Maizières Les Metz -Cedex- France, {nicolas.legrand,pascal.buessler}@arcelormittal.com

Flatness defects are one of the major problems in cold strip rolling. Their origin is the roll stack thermo-elastic deformation. The combination of the elastic deflection, the thermal crown and the roll grinding crown results in a non-parallel bite. If the transverse roll profile is not an affinity of the incoming strip profile, differential elongation results and induces high stresses in the outgoing strip. The latter combine with the imposed strip tension force, resulting in a net post-bite stress field which may be sufficiently compressive locally to promote buckling. A variety of non-developable shapes may result, generally occurring as waviness, and classified as flatness defects (center waves, wavy edges, quarterbuckles..., see figure 1).

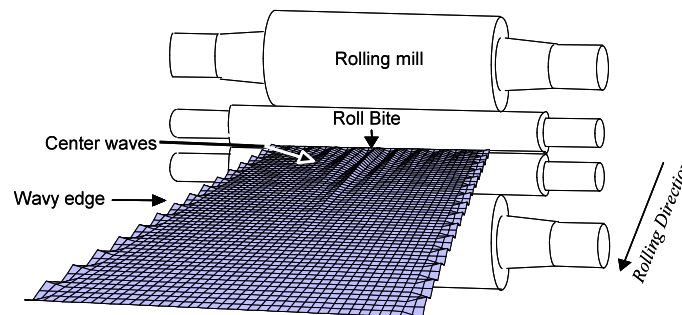


Figure 1: Flatness defects in cold strip rolling.

Predictive modeling of flatness defects has mostly used uncoupled approaches [1,2]:

- The stress field is first computed by a rolling model without taking into account buckling phenomena.
- Then this post-bite stress field is transferred into a structural mechanics model of the rolled strip (completely gone out of the rolling mill).
- Finally, buckling characteristics of the strip (modes, energies, and sometimes post-buckled shapes and amplitudes) are computed without taking into account the presence of the roll bite.

This provides useful results, but neglects possible feed-back of buckling on the system. Buckling may level off post-bite stress (the stress practically cannot grow above the buckling load), with two consequences for the “roll bite model”:

- The experiment / computation comparison becomes difficult ;
- The potentially significant impact of the change of the post-bite stress field due to buckling cannot be taken into account in the roll bite model.

The purpose of the present paper is to present a coupled approach where a sophisticated FEM buckling plate model, based on the Asymptotic-numerical-method (ANM) [5],[6] and a shell formulation, is coupled with an FEM model of strip and roll deformation, LAM3 / TEC3 [4]. Subsequently, a general rolling model is obtained, providing out-of-bite residual stress fields in agreement with experiments, and nature of flatness defects are correctly detected, as will be demonstrated on several examples (see example in figure below). The question of the interaction between the out-of-bite buckling phenomena and the in-bite strain and stress fields will be addressed. Comparing with uncoupled approaches, the capabilities of the present study will be clarified.

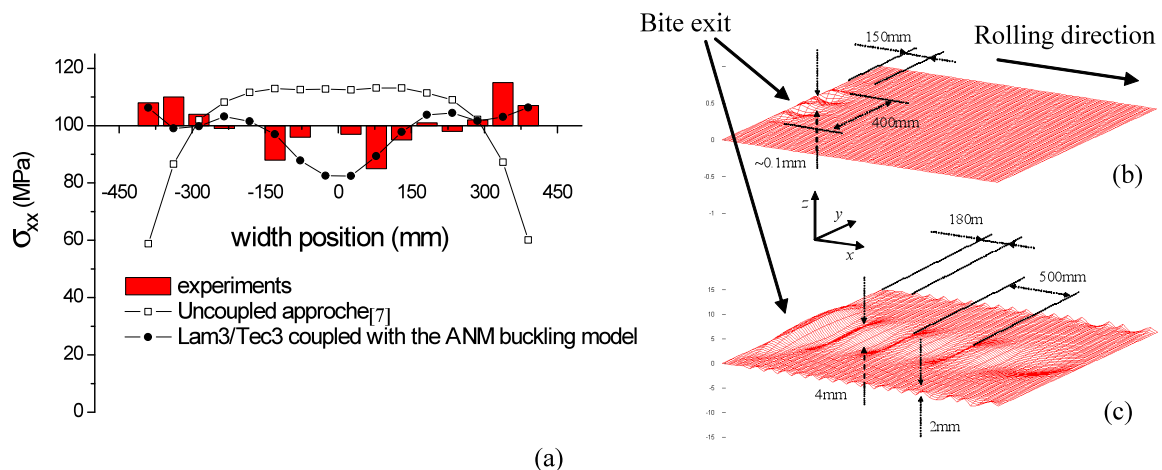


Figure 2: (a) Transverse longitudinal stress profile at 3m from the bite exit, (b) strip shape during rolling (a rolling tension is applied : flatness defects are more or less dissimulated), (c) strip shape after eliminating rolling tension (flatness defects appear or amplify).

References

- [1] T. ISHIKAWA, Y. TOZAWA, N. YUKAWA, N. YAMANAKA. "Analytical approach to the shape of rolled strip" Proc. 1st Conf. Advanced Technology of Plasticity, Tokyo (Japan) 3/9/1984 - 5/9/1984, vol. 2, p.1161-1166.
- [2] F.D. FISCHER, F.G. RAMMERSTORFER, N. FRIEDL . "Residual stress-induced centre wave buckling of rolled strip metal" J. Appl. Mech. 2003, Vol.70, p.84-90.
- [3] C. COUNHAYE. "Modélisation et contrôle industriel de la géométrie des aciers laminés à froid" (modelling and industrial control of the geometry of cold rolled steels), PhD Thesis, Université de Liège (2000) (in French).
- [4] P. MONTMITONNET. "Hot and cold strip rolling processes" Comput. Meth. Appl. Mech. Engng 2006, Vol.195, p.6604-6625.
- [5] E.H. BOUTYOUR, H. ZAHROUNI, M. POTIER-FERRY, M. BOUDI. "Bifurcation Points and Bifurcated Branches by an Asymptotic Numerical Method and Padé Approximants", International Journal for Numerical Methods in Engineering. Vol. 60, Issue 12, 2004, pp. 1987-2012.
- [6] H. ZAHROUNI, B. COCHELIN AND M. POTIER-FERRY. "Computing finite rotations of shells by an asymptotic-numerical method". Computer Methods in Applied Mechanics and Engineering 1999, Vol. 175, Issues 1-2, pp. 71-85.
- [7] S. ABDELKHALEK, H. ZAHROUNI, M. POTIER-FERRY, N. LEGRAND, P. MONTMITONNET, P. BUSSLER. "Coupled and uncoupled approaches for thin cold rolled strip buckling prediction". Proc. of the 12th ESAFORM conference, Twenty 2009, Nederland.