COIL BUILD UP COMPENSATION DURING COLD ROLLING TO IMPROVE OFF-LINE FLATNESS

Lourival Salles de Almeida Neto[1], Tuggan Ayhan[2]
[1]Achenbach Buschhütten GmbH; Siegener Straße 152; Kreuztal, NRW, 57223, Germany
[2]Assan Alüminyum; D-100 Karayolu Üzeri 32. km; Tuzla, Istanbul, 34940, Turkey

Keywords: coil, build up, compensation, off-line, flatness, improvement

Abstract

During rolling, overlaps of material with a convex profile at recoiler cause greater tension in strip center fibers than in fibers of the edges, which is known as coil build up. The high tension on central area is understood by the automation system as zones tighter than reference commanding its actuators to put back such zones on target, loosing the correspondent strip fibers. The difficulty is that the buckles created by the flatness controller are not seen at operator's screen. A coil build up compensation based on material profile was developed in order to have the cause of center buckles after unwinding reduced to the coiling process. From 24 coils with thickness ranging between 0.7 and 2.0mm, 100% presented better offline flatness. Flatness carpets related to profile suggested a paradigm breaking: perhaps we have to accept rolling with not so good flatness in order to have the desired offline flatness.

Introduction

Good off-line flatness has still been a challenge for producers of rolled coils. Although the rolling mills have been improving the ability of controlling flatness, customers are still claiming for bad flatness after unwinding. This is a strong proof that online flatness is not the only variable which determines the off-line flatness.

One known effect of the coiling process is the increasing coil stress with diameter due to the positive strip profile leading to center buckles. Understand as positive profile a bigger thickness on the center of the strip compared to its edges. The common recommendation is, then, to roll with reduced recoiler tension.

Accepting the profile of the material being rolled causing the effect mentioned and a cold rolling mill with automatic flatness control, one question arises: if the flatness automation system is detecting the increment in stress distribution along the strip width, shall it react with the flatness actuators?

The difficulty to answer this question relies on the fact the material can become tighter in a certain measuring zone because it was reduced less in that area. Even if the gap bite does not create any flatness disturbance, measuring zones in the center of the coil will still measure increasing stress due to coil build up. Thus, it was thought about integrating this conclusion to the flatness control strategy, compensating the increment of stress due to coil build up before sending the flatness measurements to the flatness control.

This paper presents the results of a coil build up compensation for flatness control during rolling of the last pass before slitter in order to improve the off-line flatness of aluminium strips in the range of 0,7mm to 2,0mm.

Cyclical Creation of Online Center Buckles

While the machine is rolling, overlaps of material with a convex profile at recoiler cause greater tension in the strip center fibers than in fibers of the edges [1]. The high tension on central area is understood by the automation system as zones tighter than reference. Immediately after this detection, the flatness control commands its actuators to put back such zones on target, loosing the correspondent strip fibers.

The hypothesis elaborated is that releasing the tightness at center area due to coil build up during rolling will create center buckles which will increase center buckles after coil unwinding.

The main difficulty is that the buckles created by the flatness control are not seen at the operator's screen. And, worst, sometimes the center buckles are visible during rolling but the operator' screen keeps showing flatness on target. This phenomenon often leads the production team to think the flatness measuring roll is not detecting the buckles, causing the machine to stop for verification.

When flatness actuators release the tight center fibers, they will do it until flatness is again on target. However, as coiling keeps going on, the tight center fibers will reappear because of the convex strip profile. Center area fibers again too tight due to coil build up will command flatness actuators to put the strip back to flatness target, increasing center buckles just after the gap. This cycle repeats until end of rolling. The conclusions:

a. There is nothing wrong with the flatness measurement device. It simply cannot distinguish if a zone is tight due to rolling or due to coil build up.
b. The material is coiled with increasing online center buckles but not seen on flatness screen because of the coil build up stress

Design of the Coil Build Up Compensation

The coil build up compensation is simply the integration of the elaborated hypothesis with the flatness control strategy. Before the measured flatness tensions are sent to the flatness controller, they are reduced by the amount of stress caused by the coil build up – characterizing the compensation developed. Doing so, the cause of center buckles after unwind will be reduced to the coiling process only.

The amount of stress reduction applied by the compensation must be near or exactly the increment of stress the coil build up causes. If the compensation reduces too much the measured tensions, the flatness control will understand the material has loose center and will commands its actuator to make them tighter. This tightness created by the flatness control allied to the center tightness created by the build up phenomenon will increase the off-line errors. Thus, tuning the compensation correctly is very important.

The compensation was designed to actuate without any information about the recoiler tension because, normally, production lines have difficulties to change production parameters without guarantees of a new practice will improve the situation.

The hoop stress in a coil during rolling increases as the coil builds up [2], especially in the center area of the coil. This characteristic requires the compensation to be stronger as the recoiler diameter increases. Although the increment on hoop stress is present since the first winding, the coils don't present center buckles on their

complete length when observed at the slitting line. Most of the coils sent to the slitter don't have measurable off-line center buckles at the end of the coil. The situation faced was like described on Figure 1. Technically, this behavior matches the observation made by D.T Oliver [3].
Observation at slitter line revealed that although the hoop stress increases with the diameter, the off-line center buckles has almost the same width along most of the strip length – region "a" at Figure 1. Then, it starts covering fewer surfaces as showed by region "b".
Looking at the decoiler diameter at slitter, it was noticed that region "b" lasts for around 200mm, not important the thickness or width of the strip. In order to understand the reason the buckles expansion rate decreases after a certain point, one coil rolled down to 0,4 mm was uncoiled until its half diameter and the profile was measured and compared to the profile measured at the casting line, when it had 6,1mm thickness.

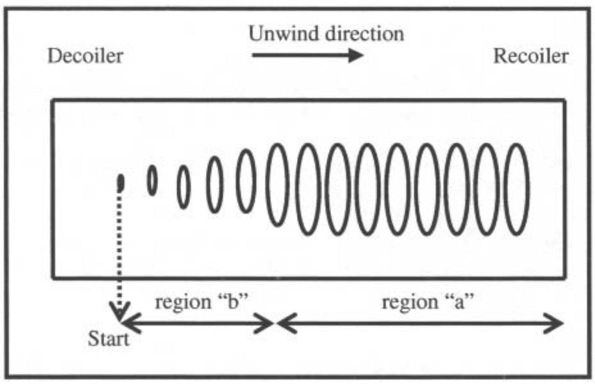

Figure 1. Center buckles characteristic at slitter line – post rolling

The profile of the rolled coil was 51% smaller than the original profile just after the caster. Relating this result with the rolling process, the explanation is that the constant generation of center buckles during rolling promotes a lower rate of stress increment during coiling and limits the buckles spread towards the edges of the strip.
The compensation was designed to actuate around the strip center line, with wideness dynamically varying from a minimum to a maximum width defined experimentally. The amplitude of the generated compensation curve continually increases with the diameter until the end of rolling as the coil build up never stops.

<u>Compensation Parameters</u>

Decided that the compensation must be as less invasive in the rolling process as possible, it is not activated until the point the center buckles are detectable at slitter line, see "Start" at Figure 1.
The first parameters to determine were when the compensation shall start actuating and how wide it must be.
The production team experience is that the buckles width expansion and point of start vary with material profile. Therefore, three coils with 1,2% profile and three with 0,6% were cast with 2080mm width. These coils were rolled down to 0,8mm and sent to the slitter.
Results, accepting a linear behavior, are showed by Figure 2. At any case, the compensation curve will reach its maximum wideness when recoiler diameter is 200mm bigger than the diameter when the compensation started to actuate.

The wideness of the center buckles duplicated with the profile, also defining a linear function for it - Figure 3. The curve suggests that if profile is 0%, there will be no build up compensation as wideness is zero.
The measured widths of the buckles were used to determine the wideness behavior of the compensation curve. For all tests made, the initial wideness was 2 measuring zones.
The amplitude of the compensation curve is defined in percentage of the amplitude of the flatness reference curve so that the compensation benefits from the customer rolling experience. It starts in zero and reaches its maximum when the coil is finished. To do it, the compensation reads the decoiler diameter as soon as the mill is rolling.
The maximum amplitude of the compensation curve and the strip profile were the only fields included on presetting screen for the operators.

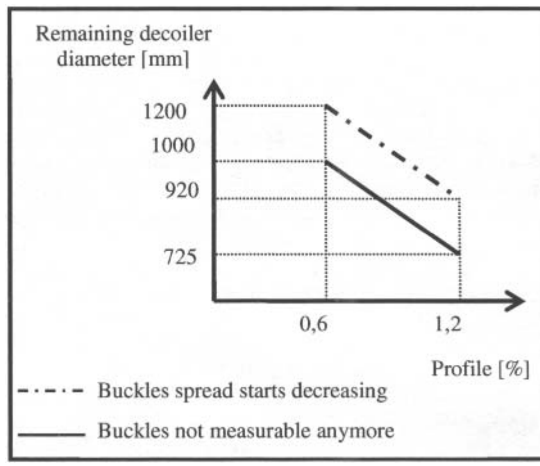

Figure 2. Determination of start point of compensation at slitter line.

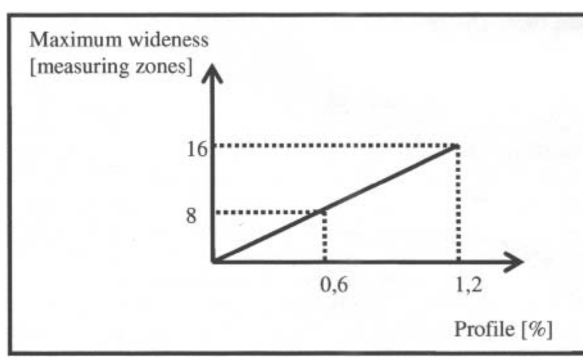

Figure 3. Maximum wideness depending on material profile

Tests and Measurements

Tests were made to prove the hypothesis elaborated and to find the best tuning for the compensation parameters. Although the compensation curve was designed to increase its amplitude and width of action as recoiler diameter increases, tests were made in opposite directions, and even with constant amplitudes and wideness, to be sure the hypothesis was correct.
The study could not disturb the normal production line. To overcome this limitation, the tests were made in batches of coils

cast together, at the same caster, for the same final product and with same profile. The batches were composed of at least two coils because one coil was taken as base coil and, thus, rolled without compensation. The remaining coils of each batch were always compared with the base coil in order to determine if the compensation gave good results. Doing so, it was not necessary to wait always for the same target thickness to be rolled.

During the test of a coils batch, all coils received the same pass before the next pass was applied to any of them. When a test batch was in progress, coils not belonging to the batch were not rolled until the test had finished. Also, it was taken care that the set of work rolls in use had rolled coils for at least two hours before tests started, suffering interruptions only due to the normal coil change procedure.

To reduce the amount of variables to analyze, the compensation was activated only for the last pass before the slitter, which was considered final product.

At the slitter, the off-line flatness was measured in five points indicated by Figure 4. After threading the material and cutting the scrap edge, 100 meters were unwinded. Then, machine was stopped and tensions released for the measurement to take place.

The next four measuring points were made when decoiler diameter was down to 1400mm, 1200mm, 1000mm and 800mm, following the same procedure: machine stop, tensions released.

On the inspection table of the slitter, the wave amplitude and length were measured and the off-line flatness calculated in I-Units.

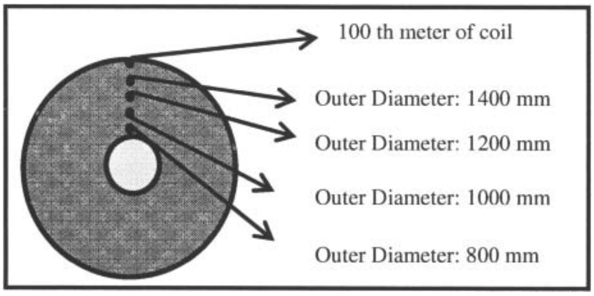

Figure 4. Decoiler diameter points at slitter for off-line flatness measurement

Results

Seven batches of tests were done manipulating wideness and amplitude.

To observe the effect of the amplitude of the compensation curve, the wideness behaviour was set to increasing mode. One coil was rolled with increasing amplitude and another with decreasing amplitude. Although both coils had better off-line flatness than its base coil, the coil rolled with increasing compensation amplitude gave the smallest average center buckles. This result was observed in all 3 batches tested: 0,84% ; 0,89% and 0,93% profile.

Although the center buckles width increases with rolling, the same test was performed to observe wideness, setting the amplitude to increasing mode. Both coils of each test had better off-line flatness than the base coil but coils rolled with increasing wideness presented undoubted better result. Wideness tests were done with batches of 0,84% and 0,89% profile.

The tests suggest the maximum amplitude shall increase with thickness – Figure 5.

Within the same thickness, more amplitude doesn't necessarily mean better result. Thin material has an opposite behavior compared to thick materials, although coils had better flatness than the base coil – Figures 6.

The off-line center buckles problem increases as thickness decreases and, within the range of study, 2,0mm strips had almost not detectable center buckles at slitter when the decoiler diameter was 1400mm or less, using low recoiler tension.

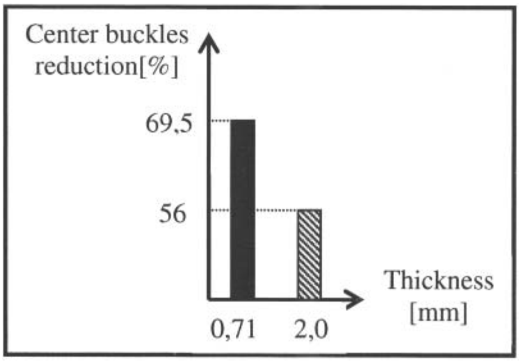

Figure 5. Same amplitude test

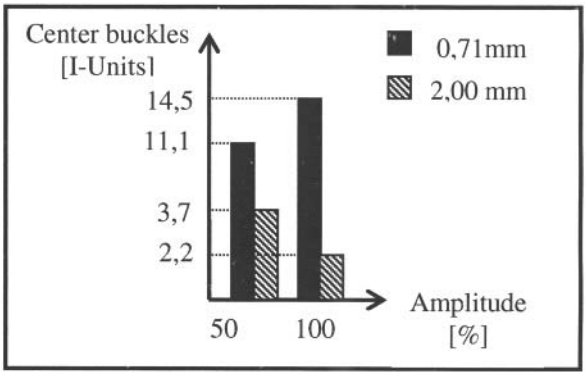

Figure 6. Same thickness test

To evaluate the effect of the compensation on this thickness, a special test was made with very high maximum amplitudes for the compensation curve: three coils were rolled with only 9,5N/mm^2 as recoiler tension. One coil was taken as base coil. One was preseted with 200% maximum amplitude and the other 350%. The coil with the biggest amplitude revealed heavy edge buckles at the beginning of unwinding procedure but at the first measuring point it already had less flatness error than the others.

One more evaluation about the behavior of the compensation curve amplitude was to roll coils without an automatic increment of the amplitude of the compensation curve. The coils didn't present good improvement compared to the base coil, reassuring the amplitude must increase during rolling.

The coil with constant 60% of amplitude was over compensated in the beginning of rolling, causing online center buckles as flatness controllers understood the strip was too loose. Then, at the end of rolling when it really had tight center due to coil build up, the compensation was not enough. The coil with constant 100% of amplitude also over compensated the effect of the coiling process in the beginning of rolling. Online buckles were seen from the operator's room before the flatness measuring roll. However, the average off-line flatness was better because the amplitude of the compensation was big enough at the end of rolling.

The Recoiler Tension Observation

Finally, the study confronted rolling with common recommendation from coiling process studies, which is the use of reduced recoiler tension, and the compensation created.
For this test the operators could not use the recoiler tension values from the plant process experience but defined low and high values. From the same batch, two coils were rolled with recoiler tension at $14N/mm^2$ and two at $23N/mm^2$. On each coil pairs with same tension, one was rolled without compensation to serve as base coil. Results at Figure 7.

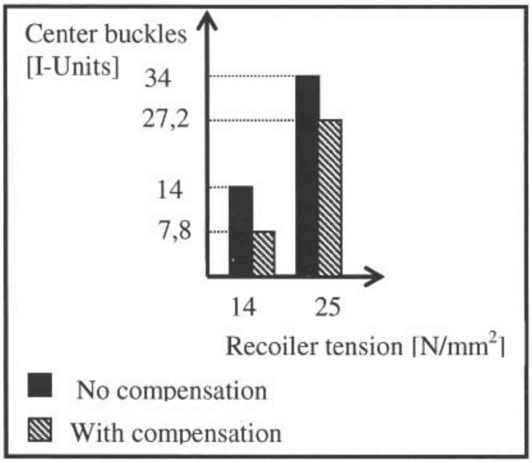

Figure 7: Compensation and reduced recoiler tension

The investigation point was to be sure that the coil build up compensation would improve the off-line flatness for a coil being rolled with reduced recoiler tension. And the result was positive.
The test also proved that the recommendation of rolling with reduced recoiler tension is correct and has an impact on off-line flatness bigger than the coil build up compensation itself.

The Flatness Carpet Observation

The flatness carpets issued by the automation system of the mill were always present during the off-line analysis. It is interesting to register here that if the flatness carpet of a coil using the compensation is better than the flatness carpet of the base coil, it doesn't mean it will present better off-line flatness. It was found that for strips with convex profiles greater equal to 0,89%, if carpet was better than the carpet of the base coil, the coil after unwinding had fewer center buckles than the base coil. On the other hand, for profiles smaller than 0,89% the behavior was mostly the opposite.

Conclusion

The coil build up compensation developed improves the off-line flatness of aluminium strips using minimum efforts from the production team. The best combination, however, is the use of the coil build up compensation with the smallest possible profiles and recoiler tensions.
The adoption of a linear characteristic for varying wideness and amplitude of the compensation curve showed well the control strategy is in the right direction.

Also, the flatness carpet observation is suggesting breaking a paradigm: perhaps we have to accept rolling with not so good online flatness in order to have the desired off-line flatness.

References

1 J. Mignon, C. Counhaye, H. Uijtdebroeks and C. Stolz, "Improvement of Coil Flatness During Unwinding" (The Control of Profile and Flatness, Birmingham, UK, 1996) 241-249.

2. D.B. Miller and D. Nardini, "Prediction of Plastic Strain During Coiling of Sheet" (Alcan International Limited, Banbury Laboratory, Southam Road, Banbury, Oxon., U.K., OX16 7SP, 1996)

3. D.T. Oliver, "Off-Line Flatness Problems in Aluminium Strips" (1st International Conference on Modelling of Metal Rolling Processes, London, UK, 1993) 518-524.

4. M. Falk, "Fiction and Reality of Aluminum Strip Tolerances" (Aluminium, Issue 74, Kreuztal, Germany, October 1998) 731-738.