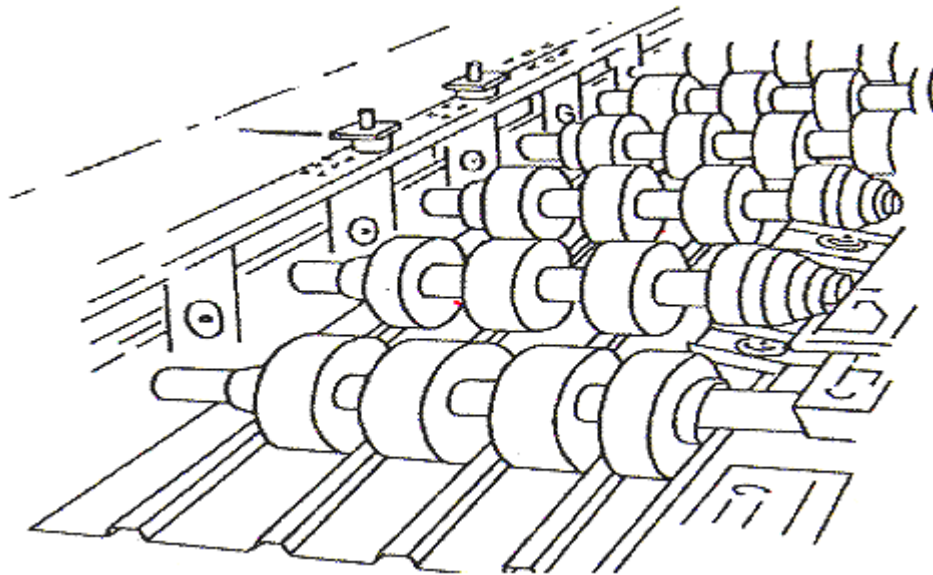




United States Steel Corporation

ROLL-FORMING GUIDE

For Building Panels



IMPORTANT NOTICE

This document provides general guidelines for the operation, maintenance, and troubleshooting of roll-forming equipment in the manufacture of building panels. In no case, however, are these guidelines intended to supersede any specific recommendations or instructions from the roll-forming equipment manufacturer.

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INTRODUCTION

Roll-forming was a major contributor to the widespread use of coated sheets for building panels. Roll-forming significantly increases panel stiffness, provides an improved architectural appearance and disguises joining seams. The process of roll-forming metal building panels is conceptually straightforward, but it must be well understood and controlled to be successful. This guide identifies and explains many of the common issues encountered in roll-forming. The factors that contribute to possible problems (material, design and manufacture) are described in order to identify the potential countermeasures to overcome these difficulties. In addition, two case studies presented in the guide highlight the examples of specific field problems and the steps taken to address them.

GENERAL CONCEPTS

Roll-forming is a process in which the shape of a metal panel is developed by gradually bending the metal through a series of roll stands, or passes. Each stand must generate the appropriate amount of deformation for which it was designed. In general, the level of deformation at each stand is not constant due to adjustments for springback and the preservation of dimension. Since the tooling is designed to control the outside dimensions of a panel, roll formers are usually designed to overwork the metal in specific stands. Problems in the forming system or tooling design may exist if materials have to be overworked in the stands/tooling other than those designed for overwork. Therefore, when roll-forming problems occur, it is important to examine each stage of the process and not merely the stand at which the problem initially appears.

The goal of a smooth roll-forming operation is achieved when there is uniform metal deformation throughout the line. Roll formers are designed to be reasonably quiet during the operation. They are not designed to run with material “popping” and wrinkling throughout the operation. If this occurs, the operation needs to be investigated.

Two basic types of roll-forming systems are utilized: a precut line and a postcut line. A precut line shears the incoming material to a specific length prior to roll-forming. During postcut line operation, the roll formed panel runs continuously and is sheared to the required length after roll-forming. Figure 1 on page 15 illustrates an example of both types of systems.

MATERIAL

One of the principal parameters that define the success of a roll-forming operation is the nature of the material. In order to design the optimal process, the tooling designer should be provided material information to be used prior to the tooling designing. This includes material mechanical property ranges, gauge tolerances and shape tolerances. In addition, different metallic coatings (hot-dip galvanized or GALVALUME^{®1} Coated Sheet Steel), organic coatings or paint will result in differences in performance even with the same set of tooling due to their different frictional characteristics.

¹ GALVALUME[®] is an internationally registered trademark of BIEC International Inc. and some of its licensed producers.

The designer requires a clear understanding of the gauge tolerance to be supplied. Ideally, a more robust operating window can be achieved if the full range of tolerance is provided to the tooling designer. The tooling designer will generally design the tooling to the thickest gauge. Ordering the tooling to a full ASTM tolerance while receiving materials with a half or one-quarter standard tolerance will produce a roll former with a less robust operating window than either the designer or the panel manufacturer intended.

ALIGNMENT

Mill alignment is critical. Since tooling is designed to specific tolerances, the forming rolls and their components must be aligned to each other both horizontally and vertically. The rolls must be aligned both side-to-side and pass-to-pass. Forming material with the gauge either lighter or heavier than that for which the tooling is designed can result in problems indicative of mill misalignment.

Using material thinner than the designed gauge can result in manufactured panels with finished radii greater than the intended design. This is usually offset by over-tightening the rolls, which causes a deterioration of tool life. Processing heavier gauge material than intended can also lead to larger radii than designed. When running thicker material, the tooling will make contact on the side of the tool radii leaving no center contact with the tooling. Since the material is not in proper contact with the tooling, gap differences from side to side become more critical. Small side-to-side roll gap differences can result in twist, bow or sweep problems.

SETUP

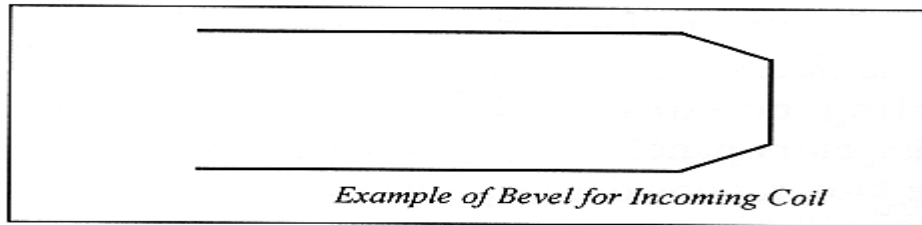
Following the initial setup by the roll tooling manufacturer, feeler or wire gauges are most often used to set the gaps on roll-forming stands. This should ideally be done each time the metal being utilized changes significantly in gauge. Operators must be sure to periodically check for tooling wear and/or machine wear. Gear and bearing backlash of as little as 0.002 inch from stand to stand can alter the shape of the finished product and produce parts that are not in compliance. The operator should maintain a logbook for the setup on each panel configuration. Additionally, the necessary adjustments made to maintain an acceptable panel should be recorded. This can be an invaluable tool for assisting other operators as well as for aiding in the maintenance of the system.

Each stand consists of top and bottom rolls designed to provide the necessary part dimensions. The position of the top roll can be adjusted via screws to change the gap between rolls, thereby changing the forming pressure applied to the metal at each stand. The final roll gap adjustment on each stand should always be down to compensate for the gear and bearing tolerances inherent to each stand.

As rolls wear, bending points can become less precise. This can alter the working surface of the roll and result in panels with radii that are less 'crisp' or precise. Roll wear is generally offset by reducing the roll gap on one or more stands. In the extreme case, this can cause a variety of problems, such as roll fight, metal marking and wandering line on the radii of finished panels. Over-tightening of stands with worn tooling can cause twist, bow and sweep.

THREADING

Tooling is generally designed to form panels from the center of the strip outwards. When threading a strip into the line, it is recommended to cut a bevel on each side of the incoming strip. This enables the strip to feed through the line on the center.



Many operators thread material into the line with a square cut edge. Although this can be successful, it often leads to problems in the later stands. If the strip moves even slightly off-center in the early stands, the problem will be magnified in the later stands. When this occurs, the operator may have to cut a portion of the strip from the line, which will not feed through the balance of the line due to jams or wrinkles. When this type of problem is encountered, often simply cutting a bevel on the incoming strip will eliminate threading issues.

CUT-OFF

Cutoff dies or shears are available in many types and variations. The most common types utilized for building and roofing panels are the slugless crop die and the flying shear, or cutoff die. The cutoff operation accurately cuts the part to the desired length in a manner that is essential to the continuous operation of the line.

Slugless crop dies generally have a short stroke length, possess contoured blades, and rapidly cut-off the finished part. Since the cut-off action is extremely fast, an accurate cut can normally be performed without an interruption to the continuous operation of the line. Proper set-up in this type of operation is critical.

Line speeds, die speeds and die clearances must be closely established and monitored to prevent blade drag. This condition can result in panel buckling. Removal of the buckled panel from the line is time consuming and may result in damage to the cutoff die, or in extreme cases, to the roll tooling. Even if the part does not buckle to the point that it jams the line, improperly timed cutting can cause problems upstream in the roll former.

Momentary interruptions in the later roll-forming stands while the initial stands are still driving material can result in a wide variety of problems and/or imperfections. Minor buckling in the intermediate stands can result in oil canning type imperfections as well as other twist or dimensional issues in the finished panel. If the line is set-up with extremely loose tooling clearances, the effect of momentary line interruption from the cutoff operation may be seen all the way to the uncoiler. In this instance, the alignment of the entire line becomes integral to the cut-off operation. For example, if the uncoiler is out of alignment, the momentary line interruption could 'pull' the material in a skewed manner from the uncoiler and potentially cause oil canning, twist or sweep problems.

A flying shear, or cut-off die, may be required with an increase in the line speed or panel height configuration. This allows the shear or die to attain the speed of the line prior to the cutoff operation. The timing of the shear is critical in this operation.

Momentary interruptions in the latter roll-forming stands, as described above, will generally be larger in magnitude and more serious in nature as the speed of the cut-off operation increases. The blade or die should always be cut to an approved part. Improperly designed/machined tools must be avoided because they result in tight clearances, induce blade drag, tool drag, or loose clearances, which result in burrs on the finished panel.

LUBRICATION

The most commonly used lubricant to aid the roll-forming of building panels is vanishing oil. This product provides the necessary lubrication for the forming process and also has the advantage of evaporating over time to permit ease of handling and installation at the construction site. However, the vanishing oil or other lubricant should contain at least 95% solvents or be a water-based lubricant that leaves minimal residue. Care should be taken to allow the roll formed panels to be completely dried prior to shipment. No lubricants should be used on either acrylic coated GALVALUME[®] or Galvanized steel that U. S. Steel identifies as ACRYLUME^{®2} or ACRYZINC^{®3}, respectively.

Inadequate lubrication can cause problems with the roll former operation and/or in the finished panel. A common problem within the roll former is the bonding (welding or fusion) of coil coated products to the roll tooling. This is time consuming to remove. Some companies have had some success by mounting SCOTCH-BRIGHT^{™4} rolls on the tooling to continuously remove coating build-up or by polishing the rolls while in operation. Problems can also extend to the finished panel. Part configuration, forming issues, oil canning, twist, bow, and improper finished dimensions can all result from inadequate lubrication.

WHAT TO LOOK FOR

With a working knowledge of the panel configuration and the roll former setup procedures, the root cause of many problems can be determined at the plant level. Generally the most important factor to keep in mind is that roll-forming issues must be approached from a systematic point of view. That is, everything must be considered from the incoming material properties, lubrication, roll former setup, uncoiler, and cut-off methods to the inspection details of the finished product. All or any of these factors can impact the acceptance of the finished part.

When observing a roll-forming line to determine the cause of a problem, two basic questions need to be addressed:

1. What is the Imperfection?

It is important to define the nature of the problem to be solved: edge wave, oil canning, panel dimension.

² ACRYLUME^{®2} is a registered trademark of United States Steel Corporation.

³ ACRYZINC^{®3} is a registered trademark of United States Steel Corporation.

⁴ SCOTCH-BRIGHT^{™4} is a registered trademark of 3M Corporation.

2. What are the Tool Gap Settings?

Gaps should initially be set at the material gauge with final adjustments made to achieve the desired final dimensions.

INSPECT THE FINISHED PANEL

1. Does It Hold Dimension?

Ensure that the material is within the ordered width and property tolerances. Check the gaps in the overbend stands for proper gauging.

2. Where Does the Imperfection Appear?

Inspect and check the tooling and gap settings where the imperfection occurs and in the stands upstream. Adjust to appropriate settings.

3. Are There Tight or Loose Areas on the Finished Panel Radii?

These imperfections typically denote improper tooling adjustment or worn tooling or bearings.

Ensure that the tooling has proper gap settings. Inspect the tooling for worn areas (chrome coating loss or increased radii due to wear). Inspect the line during operation for bearings with excessive movement. Occasionally, a worn bearing will make noise during operation. If bearing wear is isolated and is consistently in one stand, it would be prudent to inspect the tooling in the entire line for alignment, wear and proper gap settings.

4. Do the Radius Lines Appear to Wander Down the Length of the Panel?

Dry material, worn tooling, and improper tool alignment can cause this problem.

MATERIAL

1. Does One Coil Perform Differently Than the Next?

Check for and establish the differences between the two coils. Differences in gauge, oiling, and properties can affect the final part.

2. Has the Gauge Changed Or is It Out of the Ordered Tolerance?

The operator must know the expected gauge tolerance. Often tooling gaps are established around the midpoint of the range of the ordered gauge tolerance. Tooling adjustments may be necessary when working at the extreme ends of the material gauge tolerance, especially if the tooling was not designed to accommodate the full range of gauges anticipated.

OBSERVE LINE IN OPERATION When Free (No Material) and Loaded

When the Line is Running Free

1. Does the Tooling Run Eccentrically or Wander with Respect to Other Stands?

This is an indication of bent shafts, worn bearings, worn or misaligned tooling. If the tooling visually wanders from side to side, either the bearings are worn or the shaft lock-nut has come loose, or a shim has worn or fallen out. When the tooling is running in an elliptical pattern (egg shape, or up and down) the shaft itself may be bent. This will require checking the shaft for run-out with a dial indicator for the amount of movement.

2. Are There Areas Where Excessive Material Has Been Stripped Off During Forming?

This normally indicates dry material, tight clearances or improper tooling setup. Tooling stands where material slivers and/or debris accumulate should be closely monitored, as this can lead to premature wear and finished panel imperfections. Material run with insufficient lubrication (dry areas) will run with increased friction in these areas during forming. This can cause material to be scraped during the roll-forming process, especially on the panel edges. In some cases, running dry material can raise the temperature of the tooling sufficiently to reduce the die clearances from heat expansion.

Tooling that is gapped to less than the material being formed, or tooling that is out of alignment from stand to stand, can also cause this problem. Although it is sometimes not possible to prevent material debris accumulation on some stands, tooling should be gapped and checked for alignment frequently.

When the Line is Loaded

1. Does the Material Track Properly into and from the Line?

Material that has differential lubrication edge-to-edge, material with significantly different thickness edge-to-edge or tooling that is out of adjustment can cause tracking issues.

2. Does the Imperfection Appear at One Stand?

If this is the case, ensure the tooling is gapped properly at both the imperfection stand and also at the stands prior to where the imperfection occurs.

3. Does the Cut-Off Operation Run Transparent to the Line?

Drag or an out-of-time cut-off operation can induce a variety of imperfections or problems. In a post-forming cut-off process, the cut-off should not alter the continuous forming of the panel. Dull cut-off dies or knives can impart sufficient drag in the cut-off operation so that the formed panel actually begins to buckle in the cut-off operation. A similar condition is possible if a flying shear is out-of-time with the speed of the forming operation. Both of these conditions should be addressed when they first appear, as permitting them to continue will eventually cause the panel to buckle in the line prior to the cut-off.

4. Does the Material Pop, Crackle, or Wrinkle at One Stand?

This is often the result of either tooling misalignment or the material entering the rolls in a skewed fashion.

Roll-forming should be approached from a systematic point of view; each stand is designed to perform a specific amount of forming.

INSPECTION

Inspection is probably the most subjective portion of the roll-forming operation. It is important to have consistency between inspectors in order to ensure proper acceptance of panels.

Once part dimension is achieved, the visual inspection regarding the acceptable amount of oil canning, twist and bow is typically not measured and not standardized. This makes solving these types of problems difficult. Therefore, It is crucial to define standardized acceptability criteria.

Generally, plants rely on one or two people who are usually the most experienced to determine acceptability. An alternative, and preferable, practice is to develop a set of standard panels and/or panel photographs. This allows the operator to determine quickly when the roll-forming line is starting to produce suspect panels. This will enable line issues to be addressed before rejections occur. Visual standards have been found to be an extremely useful tool for solving visual imperfection issues. Additionally, it is recommended to maintain a log of imperfection type, imperfection frequency and corrective actions in order to aid in troubleshooting.

CONCLUSION

Successful roll-forming relies on a combination of factors, including material properties, tooling set-up and roll former operation. As problems arise, it may be difficult to ascertain which factor is negatively impacting the finished panel to the point of rejection. This is why it is imperative to view the roll-forming process from a systematic point of view. With this approach, it is possible to determine the root cause of the problem and take the appropriate corrective course of action.

COMMON PROBLEMS

TWIST

Twist is the rotation of two opposing edges in opposite directions. During typical twist deformation, the edges of the sheet are stretched, while the material closer to the bend axis undergoes compression. Twist in a formed part is generally the result of excessive forming pressures along the longitudinal radii.

Factors	Causes/Cures
Tooling Set Up	<ul style="list-style-type: none"> ➤ Balance roll gaps – uneven roll gaps cause twisting. ➤ Increase roll gap in area where twisting occurs. ➤ Reduce the degree of forming in several stands, sequentially reducing the deformation imparted through several stands will reduce the peak forces, allowing a smoother strain distribution and less likelihood of twisting.
Panel Design	<ul style="list-style-type: none"> ➤ Symmetrical panels should run without twist issues. Nonsymmetrical panels are most susceptible to twist.
Material	<ul style="list-style-type: none"> ➤ Changes in gauge across the width of the incoming material can induce twist, especially if the edges are thicker than the center. The edges will undergo more deformation than the center and twisting can result. ➤ Incoming material shape in the form of an edge wave (edge of the sheet longer than the adjacent area) can propagate itself as twist. Forming that works material on this elongated edge can result in unbalanced strains from side-to-side. Ordered material shape quality standards should be well known and defined.
Heat	<ul style="list-style-type: none"> ➤ Heat expansion of the tooling from the forming process can reduce the roll gaps originally set, resulting in twist. If the panel runs okay at startup and subsequently twist appears, check the roll gaps for heat expansion. The use of a lubricant can reduce temperature increase during forming. ➤ Sharp corners are a source of localized heat expansion, which can be minimized by lubrication. However, in many cases it is desirable to maintain the sharpest corner possible. This must be balanced with the roll gaps and ultimate forming pressures to minimize twisting issues.
Cut-off	<ul style="list-style-type: none"> ➤ Improperly timed panel cut-off dies can cause cut-off drag resulting in panel deformation, which appears as twist.
Roll Pickup	<ul style="list-style-type: none"> ➤ Galvanized or coating pickup on the tooling can reduce the roll gap resulting in uneven deformation, and heat buildup. Clean the rolls periodically to remove any pickup to assure conformance to designed tolerances. ➤ The use of a lubricant can reduce or eliminate roll pickup.

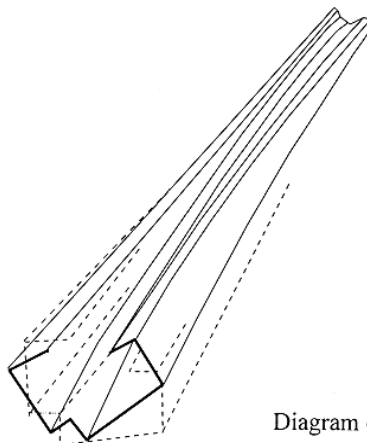


Diagram of Twist

EDGE WAVE

Edge wave is the result of the edge of the panel having been elongated with respect to the rest of the panel.

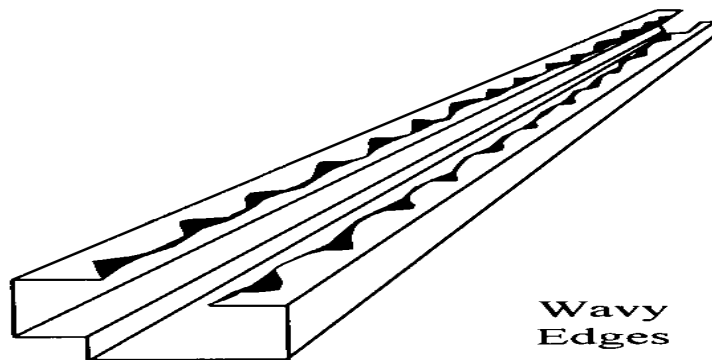
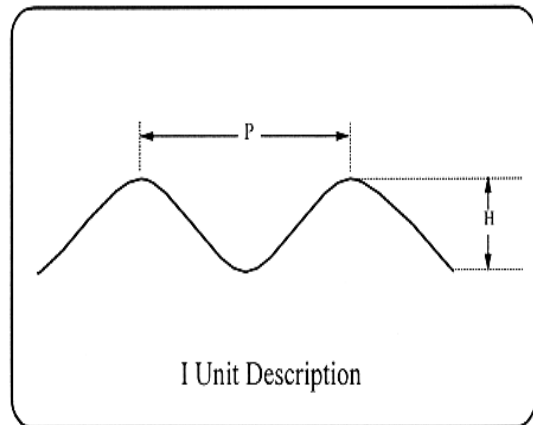
Factors	Causes/Cures
Leg Length	➤ Waves can occur because the distance from the edge to the first bend is too great, or the metal is too thin. A bend adjacent to the edge can alleviate an edge wave problem. Typically, bends at the edges should be at least 3-6 times the material thickness in distance from the edge.
Horizontal	➤ When a bend close to the edge is not possible, the operator may be able to minimize the distance condition by increasing the horizontal distance at the stands where the edge wave appears. For example, if waves appear between stands #3 and #4, the operator could place the #4 roll in the #5 stand location and leave #4 stand empty.
Lubrication	➤ The addition of a lubricant and/or raising the top rolls a little can often reduce or eliminate edge wave.
Material Shape	➤ The incoming edge shape criteria should be specified; incoming shape criteria is generally expressed in terms of I units. An I unit is the dimensionless number which signifies the amount of full center or edge wave based on the height of the wave and the length of the repeating wave.

Incoming shape criteria are generally expressed in terms of I units. I units are numerical designations applied to the height and the peak-to-peak repeat of the wave. The I unit value is calculated as follows:

$$I = (3.1415 \times \text{height of the wave} / 2 \times \text{the distance the peaks are apart})^2 \times 100,000,$$

$$(I = (3.1415H / 2P)^2 \times 100,000)$$

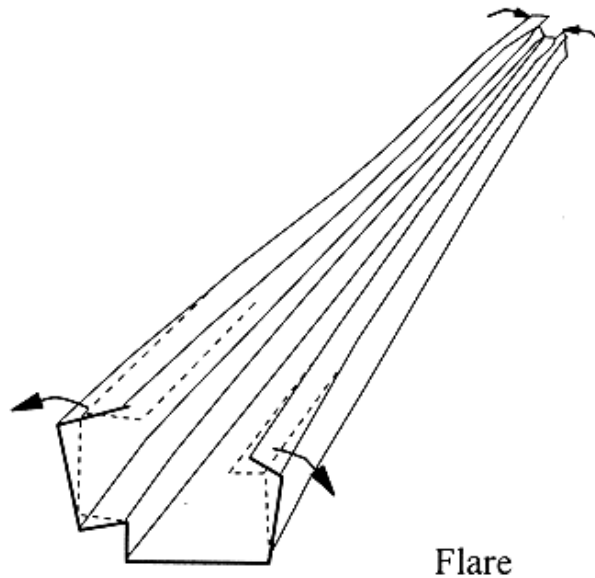
For example: A sheet with a 1/16" high wave which repeats every 12" would have an I unit value of 6.7.



FLARE

End flare is the distortion that appears at the ends of a panel in the width direction. End flare is the result of the stress induced in the material as a result of the bending operation.

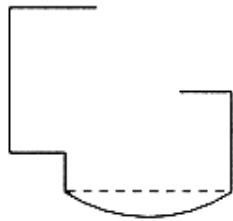
Factors	Causes/Cures
Number of Passes	➤ If the number of passes are too few, that is, too much forming is being done per stand for a given part configuration, flare can result. Extra roll passes can minimize end flare.
Pre-punched Holes	➤ Avoid pre-punched edges at the cutoff zone.
Material	➤ More ductile materials can reduce flare.
Tooling	➤ There is little an operator can do to the rolls themselves; however, the operator must ensure that the roll former is adjusted correctly.
Side Rolls	➤ Flare can sometimes be fixed by “pushing” the sides inward at the exit end of the line with idling side rolls.
Part Straightener	➤ Occasionally, the only recourse is to add a part straightener at the end of the roll-forming line.



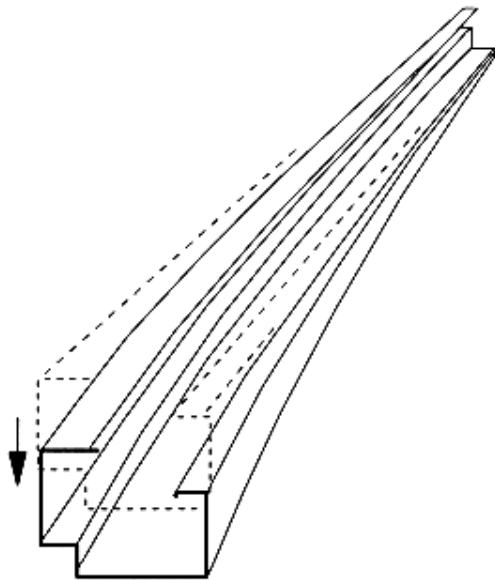
BOW

Bow is the deviation from a straight line in the vertical direction. Bow can be either cross bow, across the panel width, or longitudinal bow, along the length of the panel.

Factors	Causes/Cures
Tooling	➤ Rolls that are not adjusted properly can cause bow. Specifically, over-tightening the rolls to the point of coining the metal on single or multiple web configurations can result in large amounts of bow.
Pass Line Height	➤ Bow can also result from uneven pass line height. Check the pass line height and adjust.
Material	➤ Bow can be the result of incoming material issues such as shape or gauge variation.
Part Straightener	➤ Ultimately, some parts may require a straightener at the end of the line to correct for designed bow.



Cross Bow

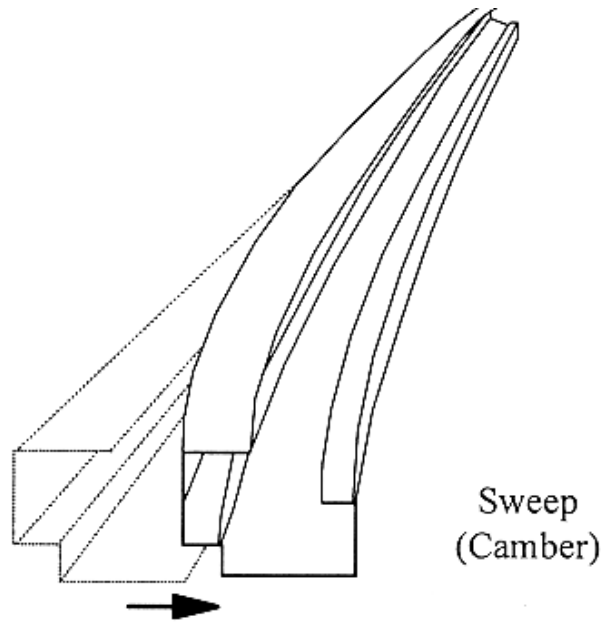


Longitudinal Bow

SWEEP/CAMBER

Sweep or camber is the deviation from a straight line in the horizontal plane of a finished panel along the length.

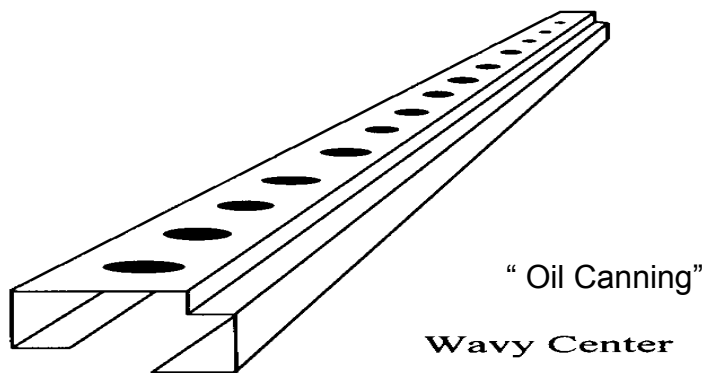
Factors	Causes/Cures
Material	➤ Sweep, or camber, can be the result of incoming material issues. Width and camber tolerances needed to develop a dimensionally accurate part must be specified for the incoming material.
Tooling	➤ Camber/sweep problems can also be the result of excessive roll gap tightness.
Alignment	➤ Shoulder alignment, spaces and roll design should all be carefully scrutinized to minimize sweep issues.



OIL CANNING

Oil canning is generally considered as simply an elastic phenomenon resulting from stresses induced during forming panels that are wide and have only their edges formed. Operators have several descriptions for this imperfection: full center, pocket wave, loose metal, panel buckling and oil canning. Oil canning is hard to measure in a finished panel although it can readily be seen in appropriate light.

Factors	Causes/Cures
Flat/Free Span Area	The general rule of thumb is that flat areas over 4-6" in width are susceptible to oil canning.
Tooling Setup	Correct tooling setup can significantly reduce oil canning, but will probably not eliminate it entirely.
Large Free Span	On panels where there is a large, flat unformed area, it is vital that the tooling be designed and adjusted properly to reduce the degree of oil canning which will be inherent in profiles with large free span area(s). As the free span to thickness ratio increases, the likelihood of oil canning also increases.
Panel Length	Oil canning can be present in wide free span profiles at one length and disappear if the same profile is produced at a shorter length.
Strain Localization	It is generally considered that tooling/material which allows a localization of strain at the bend points of the radii will produce panels less susceptible to oil canning. This approach has been effective in reducing oil canning in panels with large free span areas such as standing seam roof, or architectural panel.
Material	As the edge wave criteria, the amount of oil canning is often described in I units. Properties such as gauge, flatness, friction and mechanical properties can significantly impact oil canning in a finished panel. Subsequently, coils of the same grade can perform differently based upon variability of these properties. Thicker/higher strength materials are more likely to resist the strains that are induced at the edge of a large free span, thereby resulting in less oil canning.



CASE STUDIES

CASE STUDY ONE

A wall panel produced on a sixteen-stand roll former was considered. The material was a coated product supplied with vanishing oil. The issue being addressed was that of bow and oil canning in the finished part. After checking the incoming material and observing the roll former in operation, several items were noted.

While the roll former was in operation, the material could be heard popping as it was being formed. It was difficult to determine in which stand(s) the material was popping. By observing the bottom of the panel as it was being formed (the underside of the roll former), it was possible to actually see a wave between stands eight and nine. This was, therefore, identified as the location causing the popping.

By raising the height of the tooling in stand seven, eight, and nine, the roll former began running smoothly without any material popping and eliminated the bow/oil canning problems in the finished panel.

CASE STUDY TWO

A standing seam roof panel was being produced on an eighteen-stand roll former. The material being utilized was GALVALUME[®] Coated Sheet Steel with vanishing oil. The material was supplied as two mults slit from a master coil. The issue was that the panels produced from one mult yielded acceptable panels, while the panels produced from the companion mult from the same master had severe oil canning. After inspecting the material and observing the roll former in operation, a number of items were noted.

The first was that the gauge on one edge of the mults producing poor panels was running significantly lighter than that at the center (from 0.001" to 0.002"). Although the edge-to-center gauge difference was significant, it did not explain why the companion mult with the same gauge variation would perform acceptably. Following the observation of several mults processed through the roll former, it became evident that the mults where the lighter gauge was oriented to the operator side performed satisfactorily, while the mults with the lighter edge oriented to the drive side resulted in the problem panels.

Focusing on the first two stands of the roll former, it was obvious that the work being done on the drive side was not as heavy as the work on the operator side. Specifically, in the first two stands on the operator side, the panel configuration was set early, while the work done on the drive side was not as severe. When the lighter gauge material was oriented on the drive side, a wave was induced in the panel, which became trapped in the center by subsequent forming and manifested itself as oil canning in the finished part.

As a short-term solution, the plant began running both mults with a pay-off orientation that would maintain the lighter gauge on the preferred side. The producing steel mill then increased the edge gauge and had the processor identify the lighter gauge side of all the coils.

Figure 1: Precut and Postcut Line Drawings

