Optimal Wear for a Laying Pipe

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Figure 1: From the MPI 2003 Report: The Morgan Construction laying head. The photo on the left shows the laying head in action with hot coils of steel exiting the machine. The photo on the right shows a close-up view of the laying head. Photos courtesy of Morgan Construction.

This problem was presented at the MPI 2003 Workshop by Mr. P. Zhang, Mr. J. Walsh and Dr. B. Kiefer at Morgan Construction (which is now a part of Siemens Corporation).

Morgan Construction Company in Worcester designs and manufactures rolling mill equipment for steel plants. One particular type of rolling mill if designed to roll rod in sizes from 5 mm to 25 mm in diameter. The rod rolling mill starts with a billet of hot steel at approximately 1000°F C, which can be up to 180 mm square in cross section and up to 10 - 15 meters long. The steel is put through a series of rollers that gradually reduce the cross-section down to the desired product size. During the rolling process, the speed of the steel moving through the mill gradually increases to where it is traveling at speeds up to 120 m/s after the last rolling stage. To slow the material down for cooling and handling, a rotating piece of equipment, called the Laying Head, incorporates a curved pipe through which the rod travels to change its forward velocity into rotational velocity. The rod comes out of the laying pipe in the form of a continuous helix, which can be formed into a coil once cooled for transport. Due to friction, the laying pipe wears out and must be replaced periodically, which requires the mill to shut down production, which costs money. Therefore, the rolling mill operators want to maximize the life of the laying pipe and therefore their profits from the mill. Several studies of wear of the pipe have been carried previously. However, additional study is needed on the following:

- Numerical formulation of a better pipe curve that fits the existing laying head with minimum pipe wall wear.
- Effect of pipe bore size on pipe wall wear.
- Effect of variation of stock speed on pipe wall wear.
- Simulation of rod moving at 100 m/s inside the pipe (flexible body dynamics) and validating normal forces on the pipe wall.

The principal parameters of the proposed study are:
• Nominal diameter of laying head = 1.075 m
• \( L/D = 1.85 \) (curve height/curve diameter)
• Pipe bore diameter = 34 mm
• Stock diameter = 5.5 mm
• Stock speed = 100 m/s

What we plan to do is to develop an effective model for the laying head and the steel in terms of an effective rod theory, such as Kirchoff or Cosserat.

References

2. A book on differential geometry (review the TNB frame in your vector calculus course). For example Differential Geometry by E. Kreyszig (Dover)
3. Bring your favorite numerical methods book along with your favorite elasticity, fluid mechanics/mechanics/partial differential equations text!!