Specialised rolling mills for round and flat spring steels

The highly demanding in-service requirements of springs need both specific steel grades and rolling techniques. Currently, Morgårdshammar is focused on rolling mills for speciality steel production and has designed and installed many reference plants for the production of round and flat spring steel grades. Mill design is based around achievement of tight dimensional tolerances, good surface quality and minimising the need for offline processing.

Morgårdshammar AB, part of Danieli Group, has been involved in the rolling process, design and production of rolling mills since 1856, with its roots and experience initially in Northern Europe, and then worldwide. With several patents and inventions, both on process and equipment, Morgårdshammar is a main contributor to the modern way of long product rolling, including such innovations as the housingless concept, roller guides and advanced rolling simulation software.

In partnership with hundreds of steel producers and its own process development, Morgårdshammar products are currently focused on the field of speciality steel production. Having designed and installed many reference plants for the production of round and flat spring steel grades, we would like to share the reason behind the successful operation behind it.

The following is a summary of some of the unique features of Morgårdshammar’s technology. The basic mill layout for such specialised products is shown in Figure 1.

REVERSING ROUGHING STAND

Since the introduction of rapid electrical speed controls, fully continuous wire rod and bar rolling has dominated this sector of the market. However, due to the need for equal flow rate of material through each stand, the rolling speed in the roughing stands has become extremely slow, especially as the billet size has increased to at least 160mm².

The contact temperature in the roll gap can be approximately determined as the average of the bar temperature and the temperature of the rolls, which means that the roll surface is heated to about 600°C, while the bar surface is correspondingly cooled.

The cooled bar surface is then subjected to a considerable thermal tensile stress, and for long contact times when a deeper surface layer is cooled, transverse surface cracks are formed, which can be transformed to laps during subsequent rolling.

In material with slower transformation characteristics, like spring and tool steels, and especially in stainless steels, where no ferritic transformation appears, these thermal stresses in the surface can be disastrous. If the contact time is short, only very shallow defects are formed in the bar surface, and by further rolling, the defects can be eliminated by means of the local deformation during the subsequent passes. Deeper defects, however, which result from long contact times in the early passes of fully continuous mills, are not possible to eliminate. Instead they are opened up in the early succeeding passes, due to the tensile thermal stresses in the surface, which are acting at those low speeds.

In the rolling of special steels it has, therefore, become common for higher rolling speeds to be used at the roughing stage by using a reversing roughing stand (see Figure 2) in order to reduce the cooled depth, and thus limit the cracking to the thin surface scale layer of the rolled bar.
Morgårdshammar AB is uniquely able to propose a different type of arrangement for the rest bars on the rolling unit (see Figure 3) with several rest bar arrangements, such as the one shown in the picture with the rest bar attached directly to the upper and bottom roll chock. These make an enormous difference during rolling as it allows an exceptionally short adjustment time of the stand when rolling the same width of flat and moving to a different thickness, as is common practice in the spring flats production campaigns. This is because the level of the entry, upper and lower stripper guides automatically follows the respective roll when the roll gap is adjusted, leading to a significant time saving over a year’s production.

ROLLING UNIT STIFFNESS AND STRENGTH
The stiffness and strength of a roll neck is basically defined by the relationship between its diameter and the distance between the edge of the roll and the midpoint of the roll neck bearing (see Figure 4). This distance is uniquely short on all Morgårdshammar-designed stands, having a very short distance between the tie rods and bearings when compared with those of any other producer, thus giving a lower roll neck stress and a smaller roll neck deflection.

The rolling unit is extremely stiff and delivers minimal bending, a feature not achievable by any other rolling unit in the market, and this explains why superior tolerances are produced. Figure 5 shows an FE representation of the design. Moreover, when low temperature rolling (LTR), the loads are towards the upper load limits of the rolling units, so we believe that other manufacturers would have to use equipment with a larger roll neck diameter for the LTR application.

COUNTERBALANCING SYSTEM OF THE ROLLING UNIT
Another influencing feature of the Morgårdshammar rolling units, produced over many decades, is that the design is based on mechanical, rather than hydraulic adjustment. The advantages of such a system are its simplicity, because it requires minimal maintenance, and its safety. Hydraulic systems close to the rolling line are vulnerable to cobbles and contact with the hot material and require particular care in offline adjustment of the roll gap in the roll shop. Failure to have a ‘live’ hydraulic connection can – and has – resulted in catastrophic failure of the stand’s non-return valve, resulting in serious injuries to plant personnel.

In Figure 6, the main nut (item 1) takes the entire rolling load. The second smaller nut (item 2) is the component working with the counter balancing system and lifts the roll chock so it is always in full contact with the thread surface on the mill screws and the spherical washer surface (item 3) under the main nut. This has the advantage of
mechanically pre-loading the roll chocks with a reliable
and maintenance-free solution.

COOLING BED AREA
A further significant feature of the technological
development is the design of the cooling bed, ejection
and braking system. As shown in Figure 7, the inclination
angle of the rollers and the three-position brake-slide of the
run-in roller table is reduced compared to other brake-slide
designs. This means less friction and load on the static side
wall, with the roller table taking the major share of the
load. During braking and ejection, the lifting flaps move
radially about the turning point until sliding of the bar into
the first notch occurs. This system reduces scratching of
the bar, and contributes to improved surface quality.
The cooling bed system has an integrated pack and de-
pack annealing system that enhances the inline annealing
(see Figure 8).

PROCESS
The rolled bars must be free from surface defects and
decarburisation, as well as having a good internal structure
and correct mechanical properties. In service, springs are
subjected to fatigue due to repeated load oscillations, and
must withstand high and oscillating elastic strains without
rupture or local plastic deformation during long service.
Hence, the requirements on fatigue strength are more
severe than for most steel products.
The required fatigue resistance is determined by a
combination of:
- Chemical composition
- Inclusion count
- Degree of decarburisation of the surface layer
above and slightly below the 727°C line (e.g., between 700-750 °C), and then slowly cool.

Both these methods result in a structure in which all the cementite is in the form of small globules (spheroids) dispersed throughout the ferrite matrix. This structure allows for improved machining in cold cutting operations and resistance to abrasion.

ELIMINATION OF OFFLINE HEAT TREATMENT

Final hardness of the material can be related to the cooling rate. Different cooling rates give different fraction of ferrite, perlite and bainite at room temperature (see Figure 9). With slow cooling it is possible to obtain a pearlite structure with a small amount of ferrite. This gives lower hardness compared with a structure with a higher ratio of ferrite and small amounts of bainite.

There are two methods available to reduce the hardness of the material by slow cooling:

1. Insulating covers (hoods) located over the first two to three metres of the cooling bed width, where the cooling rate is highest, and determined mainly by radiation. The main influence of the hoods is to reduce the radiation from the bars and is sufficient when round bars of Si and SiCr spring steel grades are rolled.

2. Pack annealing. For flat products, hoods can be used in order to reduce the cooling rate. However, especially thin flats have a very unfavourable geometry from a slow cooling point of view. The instantaneous cooling rate is proportional to the ratio of the heat transfer area and the volume of the cooled bar, thus it is higher for flats than bars. The cooling rate is radically decreased by forming flat bar packs. This method is used for Si, SiCr, CrV and CrMoV spring steel grades. A common demand with this method is to control the setting of the dividing shear to form equal lengths to help control cooling rate and straightness.

CONCLUDING REMARKS

Today, Morgårdshammar is the leading partner of several special steel producers around the world. The company provides services with unique packages such as the most accurate rolling simulating software – WICON – the widest and best quality range of roller guides, a broad series of academies for guides and roll pass design, service agreements for enhancing higher performance in quality and production, and the only wire rod block specifically designed for special steel grades and super alloys. MS

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