ROLL QUALITIES AND ECONOMIC UTILISATION OF ROLLS

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1. ROIL QUALTITES

Rolls do the most important work in a rolling mill. They constitute a very important component of the running cost of the mill. Therefore it is imperative that optimum performance be obtained from the rolls.

The roll has mainly three parts -- Wbbblers, Neck and Barrel. The wobblers are for driving or rotating the rolls, the necks are to support them in the mill housings and the barrel portion is the working portion of the roll where actual rolling takes place.

Requirements of a roll:

- Resistance **to breakage:** The roll should be strong enough to roll materials without breaking.
- Resistance **to wear: It** should be wear resistant so that maximum rolling can be done with high dimensional accuracy and surface finish.
- Resistance **to fire cracking and spalling: The** roll surface should not develop fire cracks or spall.
- **Good surface finish:** It should impart good surface finish to the rolled product.
- **Good biting properties: It should** be able to bite the rolled stock well and not slip easily.

It is not possible to get all the above mentioned qualities in a single roll material. Therefore a roll designer has to select the best material out of those available to suit the requirements. Generally it may be said that the harder the rolls, better the wearing properties, less tougher they are and vice-versa.

2. CLASSIFICATION OF ROLL MATERIALS

Roll aterials fall into three main groups:

(a) Steel base
(b) Iron base
(c) Special materials like tungsten carbide and high speed steel

2.1 Steel Base: Rolls

These may be cast or forged.

(a) Cast steel rolls: These rolls have qualities and grain structure like steel although the carbon content may be quite high (upto 2.5%). The cheapest rolls in this group are plain carbon steel rolls. To get better wearing properties, molybdenum and chromium are added and nickel is introduced for imparting strength and resistance to fire cracking. These rolls with small quantities of alloys are used in big size mills such as Blooming Mills. The most used rolls in this group are called 'Adamite' rolls. Depending upon carbon content these adamite rolls are graded as A, B, C, D & E, Adamite 'A' being the softest but toughest and Adamite 'E' the hardest but least tough. All these rolls are cast, heat treated and machined and have nearly uniform hardness throughout the transverse cross section.

(b) Forged steel rolls: Rolls are also made by forging. The forged rolls contain less carbon compared to cast rolls because high carbon content would cause cracks during the forging process. The structure of forged rolls is denser than that of cast steel rolls and therefore, are tougher and can take more load. However, because of the lower carbon content the hardness is low and more prone to wear than cast rolls. These rolls are primarily used where they have to withstand high loads as in Blooming Mills or in Heavy Section Mills. Forged and hardened rolls are also used as back-up rolls in 4 high mills although normally alloy cast steel rolls are used for back-up.

2.2 **Iron Base Rolls**

These are maximum used in rolling mills mainly because they impart good finish and posses good wearing properties. Many years ago cast iron or chill cast iron rolls were only used. To increase the strength, finish, wearing properties and heat resistance, a number of alloying elements, are now added to the iron rolls. Also the improved casting techniques and heat treatment have greatly enhanced the properties of these rolls. There are a large variety of cast iron rolls available in the market but only a few representative ones are dealt below:

(a) **Chill cast iron:** The roll casting is made vertically with barrel in chill moulds. The chill surface is very hard and imparts good finish. These rolls are used for rolling flat products like sheets and plates and small sections. The addition of molybdenum increases the strength and heat resistance properties. The composition is more or less similar to cast iron but its structure is different. The outer surface of the barrel is chilled (Fe_3C) imparting very high hardness. The thickness of the chill varies. It may be even upto 20 mm thick depending upon its application. Beneath the chill zone there is a transition zone known as Mottle Zone where carbon is gradually flaking from a few specks to the full flake. The core portion is called Grey. Hardness drops down if the chill is worn out.

(b) Nichillite rolls: These are also chill rolls but nickel is added to them to impart high hardness and strength. The high hardness provides good surface finish to the product. The hardness characteristics are same as that of chill rolls. These rolls are used for flat rolling. In TISCO these rolls are used in the Finishing Stand of Strip Mill.

(c) Alloy grain rolls: As the name suggests alloy grain rolls are made from iron having carbon more than 3% with nickel, chromium and molybdenum added as alloying elements. The free carbon is present in the form of flakes. These are sand cast rolls and have reasonably good strength and wearing properties. These rolls are useful in section rolling mostly in the intermediate passes where light drafting is possible. The hardness drop from surface to core is gradual.

(d) Indefinite chill rolls: These are alloy iron rolls and are cast in chill moulds. After casting the hard top chill layer is cut off and the remaining part of the roll has hardness practically constant upto a great depth. In fact drop in hardness from the surface to the core of the roll is gradual upto 4" to 5" depth compared to chill roll where the drop in hardness is sharp. Therefore indefinite chill rolls are used in the intermediate and finishing stands of Section Mills where deep grooves may have to be cut to make the required profiles for the sections to be rolled. These rolls have better resistance to fire cracking and spalling than the chill rolls and also better strength. They are reasonably tough with good wearing properties. In TISCO these rolls are used in the intermediate stands of Strip Mill.

(e) Spheroidal graphite rolls: This is another type of alloy iron rolls where the structure is completely different from that of cast iron rolls. The carbon is present in the form of spheroids or nodules which increases the ductility and makes the roll more resistant to fracture. Nodularisation is achieved by the addition of calcium silicide and magnesium or cerium. The nodular structure of carbon imparts better tensile strength than that of cast iron along with better wearing properties. However, such rolls are more prone to fire-cracking and need lot of external cooling. Due to greater strength such rolls are used to replace other types of iron base rolls. Their wearing properties are also better than steel base rolls and at times they are also made to replace steel base rolls. The hardness drop in such rolls is minimal. In TISCO these rolls are used in Medium & Light Structural Mills, Sheet, Bar & Billet Mills, Merchant Mill No.II and also in 32" Reversing Mills.

(f) Double poured rolls: In order to obtain both high resistance to wear and high strength, roll makers have developed a roll making technology wherein the outer shell is made hard and the inner core tough by double pouring of metal of different compositions. The shell composition is maintained to give very high wear resistance properties and the core composition to give more strength. These are very costly type of rolls.

(g) Centrifugally cast rolls: The composition of centrifugally cast rolls is more or less similar to that of double poured rolls. First, metal which gives high hardness and better wearing properties is poured in the mould, which is then revolved at high speed. After sometime molten metal of different composition is poured in for the core of the roll to make it more tough. These rolls are superior to double poured rolls as the shell portion is more dense giving better properties. Double poured and centrifugally cast rolls are also known as Duplex Rolls.

(h) Tbingsten carbide rolls: The demands of modern high speed Rod Mills having No-Twist Finishing Blocks brought about the development of special roll materials particularly tungsten carbide as an ideal roll material. In tungsten carbide rolls, tungsten carbide is the major alloying constituent which gives the roll high wear resistance and hardness. The other constituent is the binding material cobalt although nickel has been increasingly used in the last few years. The general use of a single carbide grade throughout the entire finishing block is not always the optimum solution. Atleast two or more grades must occasionally be considered. TUngsten carbide roll manufacture is a highly specialised field involving metallurgical, chemical and mechanical processes. After selecting the powder composition, the main stages from powder to finishing roll block are pressing, shaping and sintering. Sintered roll blanks have a maximum outer diameter of 500 mm. Once the sintering process is complete carbide rolls reach their peak hardness and are then more difficult to machine. Mostly they are ground by the manufacturers and supplied to the users to make the necessary roll passes.

Some Rod Mills also use high speed steel instead of tungsten carbide for rolls of the No-Twist Finishing Block.

Annexures I & II give the types and qualities of rolls used in TISCO.

3. ECONOMIC UTILISATION OF ROLLS

Rolls are very expensive item of the Rolling Mill. Therefore proper care in selection and utilisation of rolls is of extreme importance. If the rolls fail in service or do not give the expected satisfactory life, it adds upto the cost of production. The cost of rolls varies from Rs 70/- to Rs 100/- per kg depending upon type and quality. Wear and breakage of rolls should be avoided as far as possible.

Further, the roll breakage not only means a full loss of an expensive roll, but along with it damage to guides, rest bars, chocks, driving systems, etc. In the event of a roll breakage there is loss in production due to mill stoppage for several hours; if the roll failure occurs in a primary mill it will hold up the Finishing Mills as no steel can be supplied to these mills and also hot ingots may have to be put in stock.

To avoid the above losses the rolls should be properly designed and carefully used.

The roll consumption in mills rolling flat products is always high mainly due to the following reasons:

- o high rolling loads.
- o flat products require better surface finish and therefore the roll changing is more frequent.

Rolls consumption can be reduced by some of the following actions:

- Improving roll quality so that the rolls do not wear fast. In TISCO harder rolls have been introduced in Merchant Mill Finishing Stands, Nichillite Rolls in Strip Mill, SG Iron Rolls in Sheet Bar & Billet Mills (at the 32" Reversing Mills) and Medium & Light Structural Mill (for rolling beams and channels).
- Increasing the working range of the rolls by starting with bigger size rolls as done in TISCO's Blooming Mill No.I, Sheet Bar & Billet Mill Nos.I & II and presently being contemplated also in Merchant Mill No.II.
- Salvaging damaged/scrapped rolls fiich is being done extensively in TISCO. The damaged rolls are salvaged by welding e.g rolls with damaged journals. Several scrap rolls of bigger mills are being machined and converted to rolls of smaller mills and used.
- Avoiding roll failures through improvement in the roll designs and faulty handling.

3.1 **Roll Failures**

Roll failures can take place primarily due to two reasons:

(a) Defects in manufacture or design of roll
(b) Faulty handling

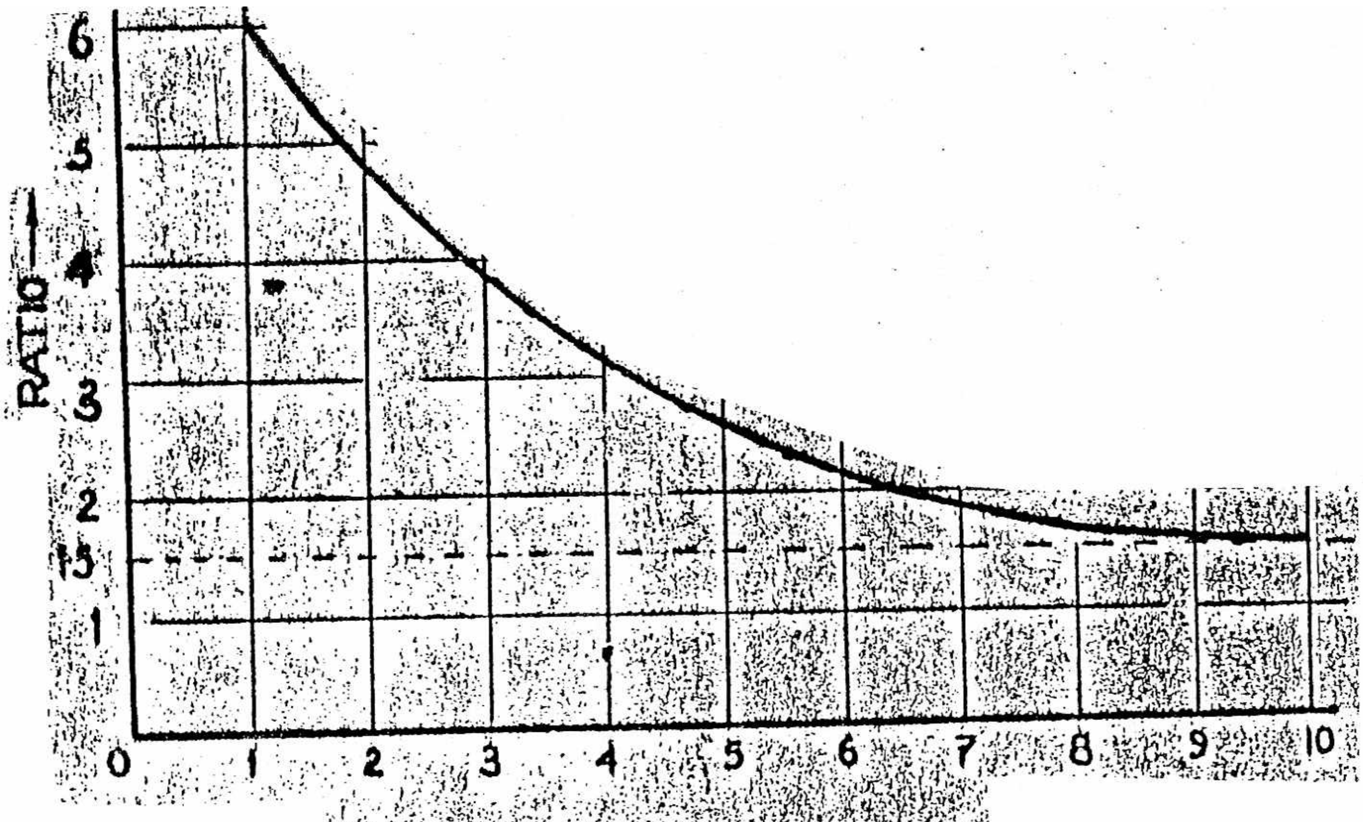
The manufacturing defects would have to be dealt with, in the course of a separate lecture on 'The Manufacturing of Rolls'. However some examples of design defects which we have overcome in TISCO are mentioned below:

3.2 **Design Defects**

(a) Neck fillet radius: The neck fillet radius should be generous so that there is no undue stress concentration. The fillet radii of roll of several mills in TISCO e.g Medium & Light Structural Mill rolls, Plate Mill rolls, Strip Mill rolls have been revised over the last few years. This has given good results causing reduction in roll breakages at neck fillet (Figs.1 & 2).

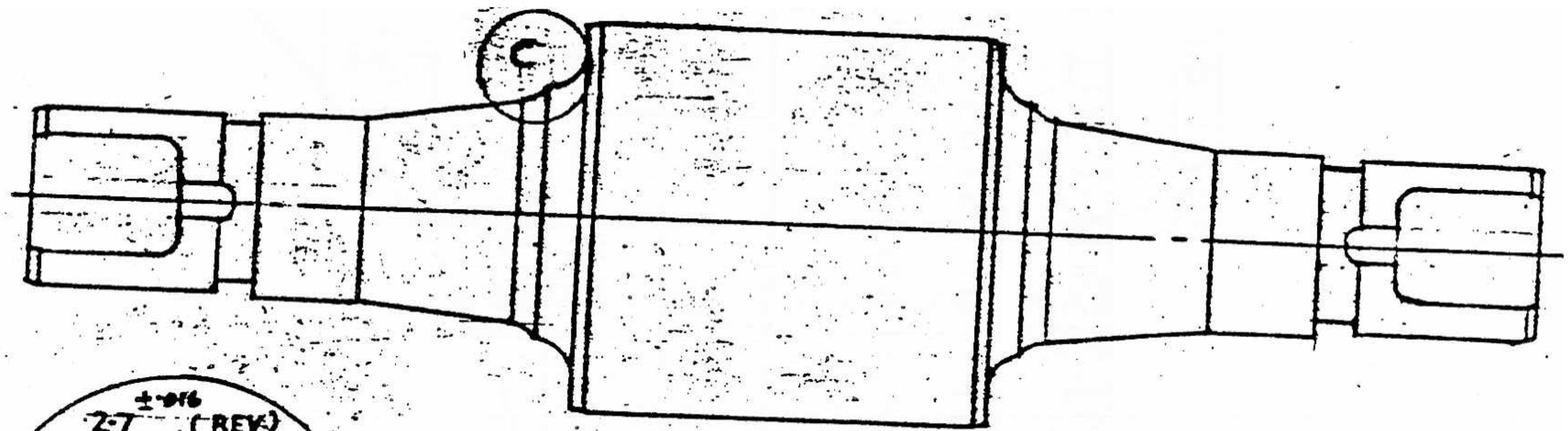
(b) Pass fillet radius: Special attention has to be given to this also because rolls can break at collar holes if the filler radius is too small. The fillet radii have been specified in roll pass layout drawings, to ensure that during machining of the rolls these fillet radii are maintained. These fillet radii have been carefully fixed keeping in view the permissible corner radii at collar. Further in the finishing passes for angles and channels where the corners are theoretically supposed to be sharp, a nominal radius of 1 to 1.5 mm is recommented to minimise the effect of stress concentration. Both these actions have resulted in reduced roll breakages (Figs.3 & 4).

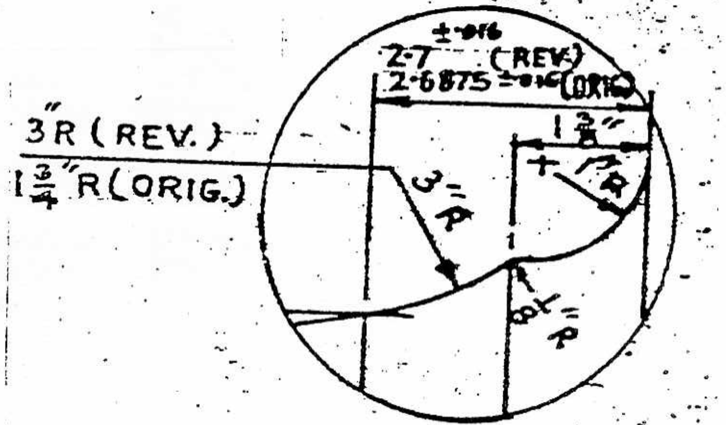
RATIO = $\frac{\text{MAX. STRESS AT FILLET.}}{\text{AVG. STRESS IN ROLL.}}$



SHOWS THAT IF FILLET RADIUS DECREASES FROM 10 MM TO 1 MM THE STRESS RATIO INCREASES FROM 1.5 TO 6.

fiG.1

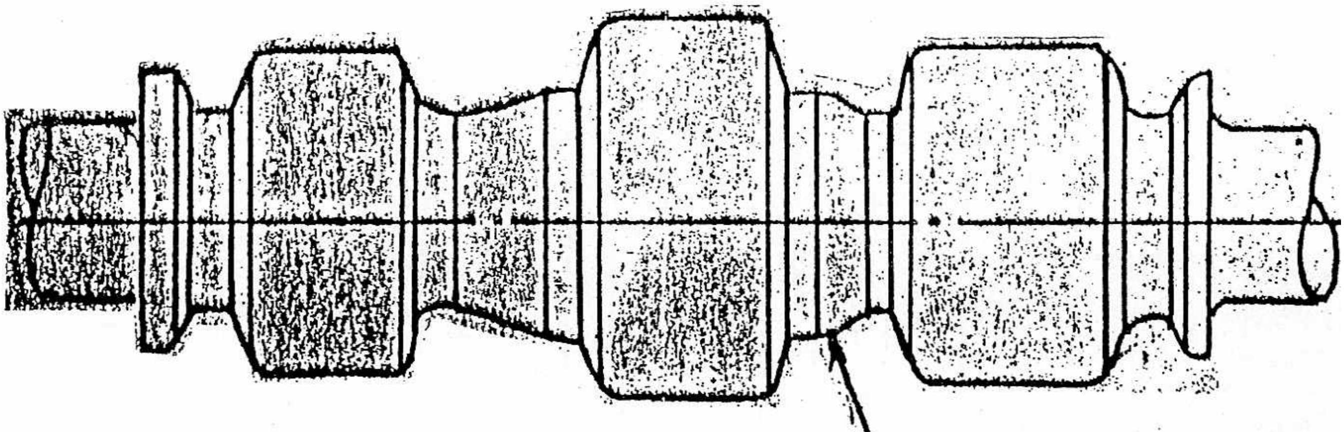




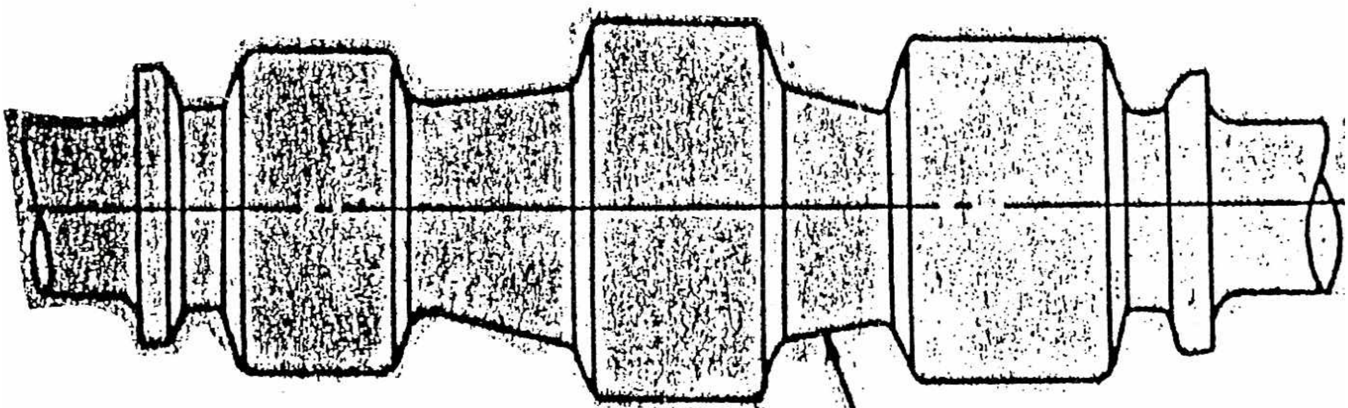
DETAILS AT-C

FIG.2

OLD DESIGN

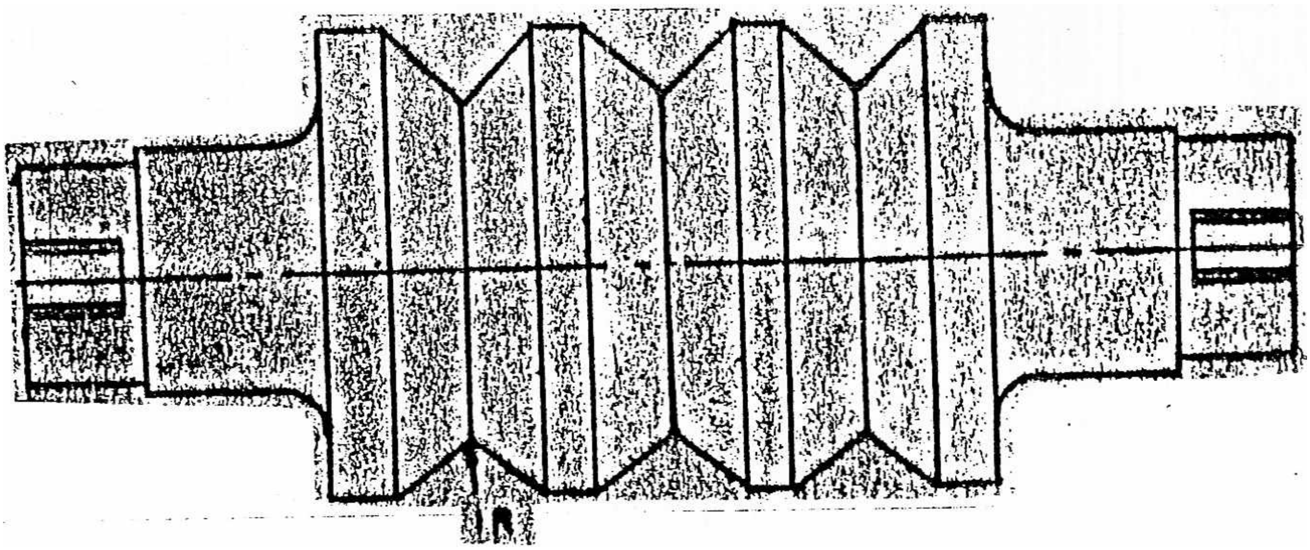


REVISED DESIGN



REMOVAL OF
SHARP STEPS ON COLLAR HOLES TO AVOID BREAKAGE

FIG.3



ANGLE FINISHING PASS WITH 1-R

BEAM FINISHING PASS WITI-1 1.5 R
(sharp corners removed to
avoid stress concentration)
FIG.4.

(c) Wobbler design: A roll can break at the Wobbler if the design is too weak. A good example from TISCO is the change of design of Plate Mill rolls from 5-pod wobbler design to flat wobbler design (Fig.5). Several years ago the wobbler design of Sheet. Mill rolls was also changed. Similarly the palm end design of 40" Blooming **Mill** Cogging rolls was changed because of excessive breakages of fork.

(d) Other design aspects of roll: Rolling of sections causing excessive load on rolls can be a cause of roll breakage e.g heavy beam sections at Heavy Structural Mill, wider and thinner sections at Strip Mill. This can be remedied by intermediate heating of the .stock or avoiding the sections which become uneconomical due to roll breakages. The pass design and pass sequence should be made such that the rolls do not get over loaded.

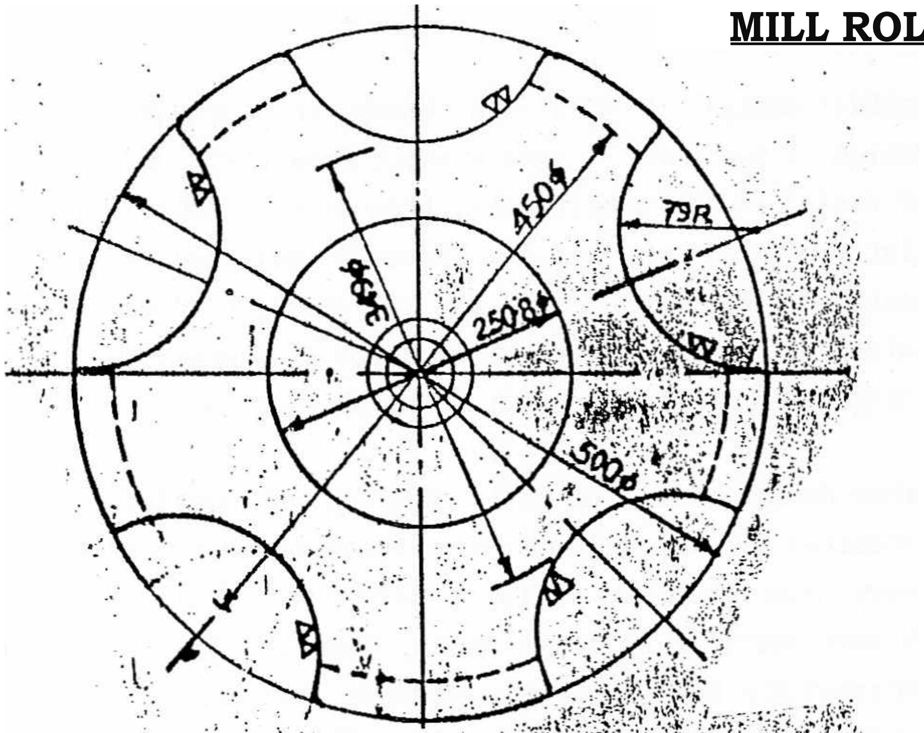
Some of the design defects cannot be overcome and also it always may not be possible to make changes in design. Under the circumstances, roll material should be changed and if possible a stronger material used instead, sacrificing a bit of wearing properties e.g in TISCO, some forged steel rolls were being used instead of cast steel rolls at 28" Reversing Mill of Medium & Light Structural Mill for rolling beams and alloy steels and SG iron rolls are being used in place of indefinite chill rolls in intermediate stands of 24" mill of Medium & Light Structural Mill for rolling beams and channels.

3.3 **Faulty Handling**

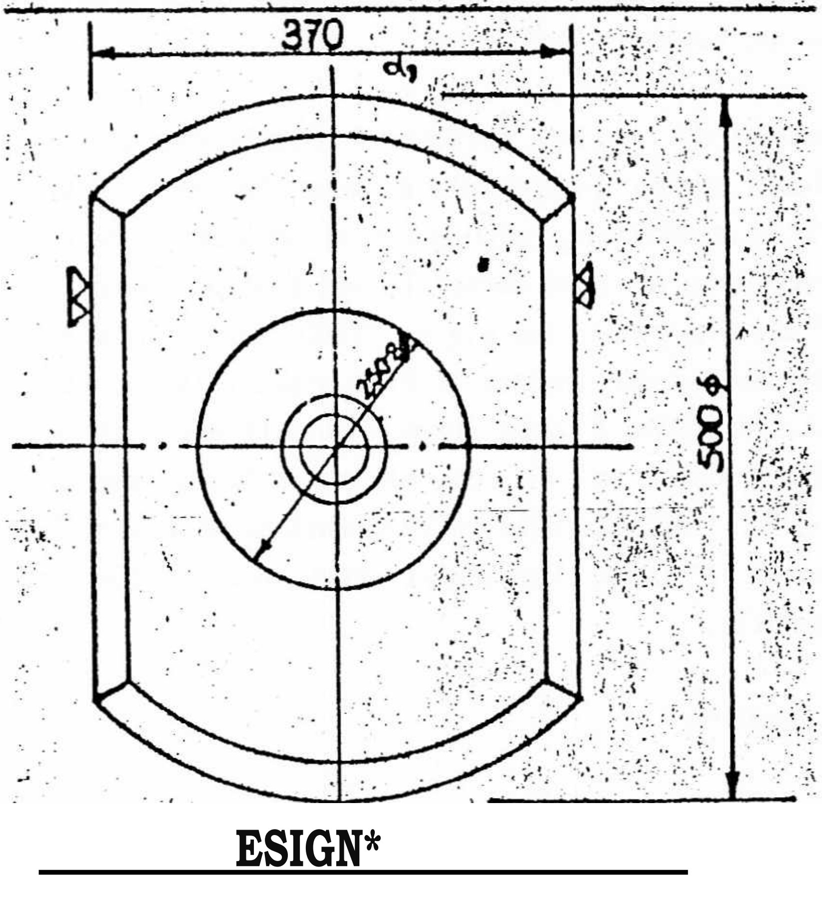
Damage to the rolls can be avoided by using them carefully and avoiding mishandling. The following factors are responsible for breakage of rolls during use. Rolls becoming weaker during use. There are three main causes:

LPOb W04313L-EFk VS. 2 POI/Ii\Aat_.PLI-- ELATE...

MILL ROLL %



OLD DESIGN = 5 POD W BLER.



ESIGN*

FIGS

(a) Fatigue: In every revolution during rolling the stress in the rolls get reversed and this continuous reversal of stresses leads to fatigue and over long period initiates cracks. Fatigue cracks are even visible and suitable action should be taken to remove such cracks before further using the roll or discard the roll to avoid mill delay due to breakage.

(b) Fire cracks: These are caused by alternate heating and cooling of rolls by accidental stoppage of cooling water when the roll surface becomes hot suddenly and fire cracks appear when the cooling water circulation is re-established. If such a situation OMITS, the rolls should be allowed to cool down slowly before re-starting the water circulation. Fire cracks also result due to over heating of the rolls. They have a tendency to go deeper with use. The cooling water can get entrapped in the crevices of fire cracks and turn into steam; the pressure thus generated aggravates making the crack deeper and wider and the situation becomes worse with alternate bending of the rolls during rolling. Efforts, therefore, should be made to remove the fire cracks by dressing when they are shallow in order to make the roll healthy again. Ideally, the roll should be dressed as soon as the fire cracks are detected.

(c) Roll diameter wear: After every rolling the rolls are dressed and the diameter becomes smaller making the rolls weaker. Added to that is the effect of fatigue cracks and fire cracks. The smaller rolls should, therefore, be carefully inspected before reuse and should be scrapped if their diameters becomes 10% below the nominal size of the mill.

(d) Roll fixing in the mill: Roll bearings and driving coupling play vital part in getting full life out of rolls:

- The roll bearings and chocks should be properly maintained. If the chocks play in the housings or if they are not properly located or if the bearings are loose, the chocks or the rolls will jump with every bar rolled resulting in shock load on the roll which can lead to roll failure. The shape of the bearings should match the shape of the roll neck especially in the taper roll neck bearing. The inner races of roller bearings and the diameter of journals should properly match.

- Where fabric bearings are used the water circulation should be perfect. If the fabric bearings do not get cooling water they would get burnt and cause damage also to the roll necks. Such roll necks would require to be repaired and polished before reuse.

- The roll driving couplings should be properly maintained. Too much play damages the roll wobblers. The alignment between the driving couplings and the rolls should be as good as possible to avoid breakage of roll wobblers.

(e) Overloading of rolls: This is a major cause of roll breakage. Most of the mills do not have stress gauges or any other measuring or recording devices for mill loads. The overloading of mill rolls does not always show up on the motors particularly where several stands have a common drive. In such cases many a time it happens that the roll breaks without showing any sign of overloading on motors. The rolls may break suddenly by bending at the time of bar entry without any effect on motor load. The overload can be due to several factors:

- Entry of double bar, folded bar, forging body or 'tongs' on bar or split end of bar.

- Overdrafting which may cause over-loading and generally takes place where adjustments are made with every pass e.g in Reversing Mills. Overdrafts are also possible when the previous stand roll is broken in a Continuous Mill -- sometimes two or three rolls have broken at a time due to this reason.

- Cold Bar -- Cold bar needs much more power to reduce and may cause a roll failure. Cold bar may also results when there is a delay in rolling schedule. Quick decision will have to be taken whether the bar temperature is sufficient for rolling. Particular in the night time the bars look hotter than during the day time, which may lead to a wrong judgement and result in more failures during night shift.

- Collar -- When the bar does not get out from between the rolls but due to some reasons goes round the roll it is said to have 'Collared'. This is a definite cause of roll breakage and often damages other Mill equipments. Collaring is due to guide failure or split end or pipy bars.

- Under Feeding -- This means that the bar has entered in a place other than the roll pass and often results in roll failures.

- Rolls or Passes not Changed in Time -- If the pass is not changed in time it gets unduly worn out and also the fire cracks penetrate deeper. The undue wear in the pass will also not give the designed shape from that pass. When a pass is not changed in time, apart from the bad section, the next pass also gets spoiled requiring heavy dressing and thus losing roll life; often collaring may result due to this. Therefore, even though extra production may be obtained from worn out passes, this will be at the expense of roll life because such passes will need more dressing. Besides, the rolls will be put to undue risk during rolling due to the presence of deeper fire cracks. In the case of Hot Sheet Mills if the hot mill rolls are not changed in time they become hollow and consequently run hot to get the sheets of proper shape. When the roughing rolls are worn out there is a tendency to press the screw more to get the required thickness. This generally causes spalling of the rolls.

(f) **Cooling of rolls**: Rolls should not be abruptly heated or cooled. The roll cooling should be to such an extent that the roll surface temperature is about 80°C. To get uniform cooling action the rolls should be rotated slowly even if the mill is down for some period. At any time during rolling one should be able to stop the rolls and touch the surfaces with bare hands indicating that the roll has been sufficiently cooled. During rolling,. due to contact with the rolled material and simultaneous cooling of surface by water, the temperature inside the roll would be more than the surface temperature.

As the hot bar touches the roll the temperature at the contact point immediately rises to that of bar temperature which could be 1000°C, only for a split second. In slower mills the bar remains in contact with the rolls for a longer period compared to that in high speed mills. The water cooling problems are more acute in slower mills. During rolling a part of the roll in contact with the bar attains a high surface temperature; the cooling water which comes in contact with this surface vaporizes and forms a layer of steam on the roll surface which thus gets covered by a blanket of steam and the cooling water becomes ineffective. Some high pressure jets should be made to impinge on the roll at the point where the bar leaves the roll. This will take away the steam being formed on the hot roll and expose the roll surface for cooling, the roll can then be cooled by the ordinary water sprays.

Cooling of bottom rolls is more difficult because on the bottom roll the water jets have to work against gravity and the water is not able to reach the full periphery of the roll as in the case of top roll. Moreover, the bottom jets often get choked due to the scales generated in the rolling process. Added to this the rolling crew is unable to see the cooling jets of the bottom rolls easily, unless special efforts are put in.

Whatever be the cooling process, the surface temperature changes from 1000° to 80°C during every rotation of the roll, as a result of which fire cracks develop on the roll surfaces. Special roll cooling boxes for flat product mills have been tried in some places with encouraging results with respect to roll wear and roll life.

The above is applicable to water cooled rolls. However, the cooling system for different types of rolls may be different. In case of chill rolls of Hot Sheet Mills, having to run without cooling, if water is used, the sheets will get cold and hot rolling will not be possible. We cannot reheat the packs to high temperatures because the edges will burn. Therefore the rolling has to be done without water cooling. To avoid sudden heating of rolls, the rolls are pre-heated by electric induction. The chill roll consists of three parts -- top chill (about 10 mm deep), mottle (about 25 mm deep) and grey iron. All these three components have different co-efficient of expansion. If the roll is heated suddenly, the chill expands much more than the mottle or the grey iron and thus a crack is formed inside the rolls causing a breakage subsequently.

Hot mill chill rolls are cooled by a mixture of steam and air. These rolls need cooling when their temperature exceeds the pre-determined rolling temperature suiting the contour of the rolls so that the flat products rolled are of uniform thickness. It is important that not a drop of water should be present in the steam otherwise rolls which are at high temperature will suddenly break.

4. MAINIINAhtE OF 11,1,CSTEN CARBIDE ROTLS

Thermal fatigue has got a very harmful effect on roll materials used for hot working conditions. In cases cracks which combined with corrosion and abrasive wear, threatens the service life of the pass. Although the thermal conductivity of cemented carbide is twice that of steel, it is still equally important that efficient cooling is provided.

The phenomenon of thermal cracking or fire-cracking in the roll pass is inevitable, nevertheless its progress can be checked and its effect minimised provided following steps are taken.

(a) **Re-grinding:** Correct and timely regrinding of carbide rolls is essential if the rated service life is to be achieved. To minimise and avoid roll failures caused by cracks in the pass, it is imperative to remove the cracks specially before the rolls are put back into the mill again. The problem is however to know when thermal micro-cracks have been removed from pass surface. Should there any residual cracks after the regrinding process, the next rolling campaign will start of with faulty rolls which factor equally increases the risk of roll breakage.

Todate there are no reliable instruments for measuring the actual depth of micro-crack. But there are some methods and instruments in the market that can be used to locate their position -- such as eddy current, magna flux, die penetration, etc. Other problems may accrue with grinding tungsten carbide rolls in unsuitable machines, when using the wrong grinding wheels. Therefore great care and vigilance is necessary.

(b) **Corrosion:** In many mills, corrosion is a hidden factor in the deterioration of pass form, because pitting formations are blurred or worn away by other destructive actions. Many mills experience periodic 'fluctuations in the cooling water with pH values dropping below 7, the point at which cobalt grades begin to corrode. The nickel base carbide grades can be used at pH values as low as 5 as these are corrosion resistant.

(c) **Overfilling:** Overfilling of the roll pass results in increase of the rolling level which combined with the deterioration of the roll pass will inevitably lead to roll failure. Therefore over-filling should be avoided.

(d) **Cooling:** The object of roll cooling is to retard the formation of thermal fatigue cracks and surface deterioration. By adequate and proper roll cooling the roll life in certain mills is reported to have increased by more than 500. The distribution of flow of cooling water has a decisive impact on roll performance.

(e) **Carbide grade:** Correct choice of carbide grade is necessary for obtaining optimum roll life.

Annexure-1

PHYSICAL PROPERTIES OF ROTJS

Si. No.	Material/type	Tensile strength (kg/mm2)	elong.	Hardness (deg.Sho)
1.	Indefinite chill/grain	20 to 25*	0.20 to 0.60*	40 to 75
2.	S.G.iron (pearlitic)	40 to 55	1.0 to 5.0	40 to 70
3.	S.G.iron (accicular)	50 to 60	1.0 to 4.0	60 to 75
4.	Double poured grain - Shell	15 to 20	0.1 to 0.3	65 to 90
	Core	25 to 35	0.2 to 0.4	35 to 45
5.	Cast steel/steel base/ alloy cast steel	50 to 90	1.0 to 10.0	30 to 50

* depending on the type and composition of roll

APPROXIMATE COST OF SOME OF THE ROTJS USED IN TISCO's M1TJS
(Prices are based on quotations for 1994-95 -- excluding taxes, transport, etc.)

Sl. No.	Mill	Size of roll	Quality	Wt. in tonnes	Price (1994-95) Rs
1.	40" Bl.Mill	1016x2286 P.B.(Tayo)	A.S	19.00	14,00,680.00
2.	SB&B Mill	32" rev. - 850 dia x 1800 P.B	S.G	10.40	5,50,935.00
3.	SB&B Mill	24" mill - 650 dia x 1066.8 P.B	Adam.'C'	3.47	2,60,295.00
4.	M&LS Mill	790 dia x 1220 P.B	Adam.'C'	5.95	3,85,030.00
5.	M&LS Mill	790 dia x 1220 P.B	S.G	5.60	3,35,415.00
6.	M.Mill No.2	370 dia x 800 P.B	I.0	0.90	75,000.00
7.	Strip Mill	400 dia x 457.2 P.B	D.P	0.75	84,772.00
8.	Sheet Mills	815 dia x 1120 P.B	Mo chill	7.11	3,34,240.00
9.	Sheet Mills	840 dia x 1320 P.B 3 high rgh. T/B	A.S	8.64	5,23,060.00
10.	Hot Strip Mill	1050 x 1700 P.B rgh. std.	D.P indef. chill alloy iron (with S.G core)	16.23	12,24,990.00
11.	Hot Strip Mill	710 x 1700 P.B fin. std.	Duplex iron indef. chill (centrifuga-lly cast - with S.G core)	7.85	5,89,380.00

SOME QUALITIES OF ROLLS USED IN TISCO

Roll quality	Chemical composition	Shore hardness
Steel base		
1. Alloy steel	[illegible]	[illegible]
2. Adamite 'C'	[illegible]	[illegible]
Iron base		
Mo.clear chill	[illegible]	[illegible]
Alloy indef.	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]