International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 05, May-2015

A Case Study of Bending of TMT Steel Bars

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***Abstract*—Thermo mechanically treated bars are preferred over conventional mild steel bars because of their superior tensile properties. But increased strength and toughness of thermo mechanically treated bars create problem during subsequent manual bending operation. Hence, there felt a need of adoption of machine bending operation. In this paper the problems associated with the manual bending operation and subsequent adoption of the machine bending are discussed. A systematic study reveals that there is a substantial improvement in the quality of the bending. More uniform bend products are produced. Productivity is also improved because of reduction in time of bending. Along with the quality of the bending there are saving in terms of the floor space area and labor cost.**

Keywords—TMT bars; Manual bending, Machine bending, Cost, Non unifom bending

I. INTRODUCTION

Thermo mechanically treated (TMT) bars are nowadays a fundamental requirement for construction in India and abroad. TMT bars have improved properties such as yield strength, ductility and toughness and corrosion resistance over Torsional bars. The multilayered microstructure having soft ferrite-pearlite core of TMT bars enables them to bear dynamic and seismic loads. TMT bars have high fatigue resistance to Dynamic/ Seismic loads due to its higher ductility. This makes them most suitable for use in earthquake prone areas [1]. With the above properties, TMT steel is also highly economical and safe for use and hence finds wide application in the areas of construction of roads, buildings, bridges etc.

TMT bars are most preferred because of their flexible nature and fine welding features. TMT bars (having low carbon content) can be used for welded joints without reduction in strength at the weld. External ribs running across the entire length of the TMT bar give superior bonding strength between the bar and the concrete and fulfils Bond requirements as per IS: 456/78 and IS: 1786/85.

The TMT process gives the bar superior strength and anticorrosive properties [2]. Controlled water-cooling prevents the formation of coarse carbides, which has been cited as the main cause for the corrosive nature of the common bar. Another reason for better corrosion resistance is the absence of surface stresses caused by the cold twisting process.

Due to very high elongation values and consistent properties through out the length of the bar, TMT bars have excellent workability and bendability. TMT bars provide better safety of structures because of higher Strength combined with higher ductility and Bendability. Unlike cold twisted deformed (CTD) Reinforcement bars, TMT bars have high thermal stability. They are the preferred choice in the application areas such as construction of Chimney fires as they sustain elevated temperatures of 400-600^0 C.

II. PROCESSING ROUTE

TMT bars are manufactured from steel ingots after reheating in the reheating furnace or directly from the billets received from the billet caster. Reheated ingots or stock billets are subjected to hot rolling by passing through series of rolls of different cross sections with definite speed and roll pressure to form TMT bars. The finishing roll stand provides the necessary ribs on the TMT bars. Figure no.1 indicates the processing route for the TMT bars. To provide unique set of properties microstructure is developed by controlled heating and cooling. Figure no.2 indicates the cooling curve for the TMT and naturally cooled bars [3]. Rolled bars are passed through a quenching system which turns the outer austenite layer into martensite while the core remains austenitic. During further processing the bar leaves the quench box with a temperature gradient through its cross section. As the bar cools, heat flows from the bar's centre to its outer surface so as to obtain an tempered outer layer of martensite with an intermediate ring of martensite and bainite.

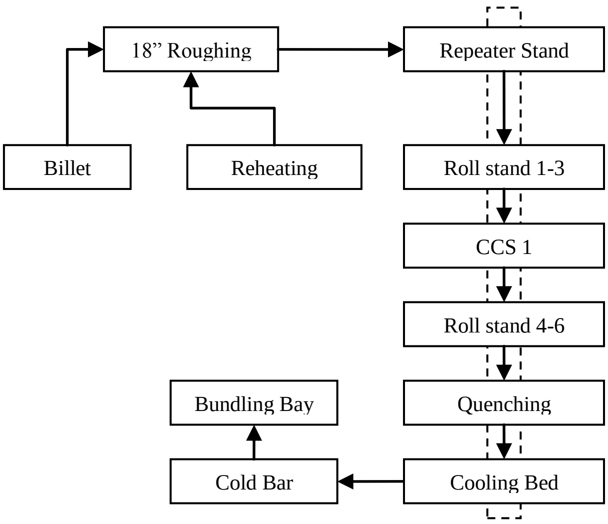

Figure 1. Block diagram of processing route for the TMT bars

Finally, the bars pass over the cooling bed for slow cooling, Quenching automatically tempers the austenitic core to ferrite and pearlite on cooling which provides improved properties such as yield strength, ductility and toughness to TMT bars. These bars are then cut into required size of about 12 meters for ease of transportation. Cut bars of high yield strength are then subjected to bending for ease of transportation. The efforts are made so as to have uniform and safe bending during this operation.

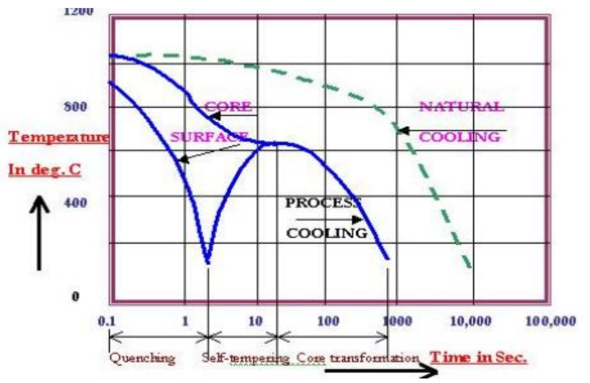

Figure 2. Cooling curve for the TMT and Naturally cooled bars [3]

III. Nature of the Problem

TMT bars are moved from the manufacturing unit to the dealers and construction sites by means of surface transportation. For ease of transportation and subsequent storage at the dealers site uniform bending of 12 meter long TMT bars is usually required so as to acquire minimum floor space and ease in handling. As the TMT bars have very high yield strength, it become difficult to bend them manually and uniformly. The non-uniform bending results in 8-9% wastage of material, A lot additional floor space was required to store the TMT bars and also leads to the difficulty of in loading and unloading. This results in excessive labour costs, poor packaging and gradual loss in the good will of the company.

IV. Experimental Work

Manual bending operation and machine bending operation was performed on three bars each of 20 mm diameter and 12 m long for this study.

A. *Non uniform bending of the TMT bars*

The TMT bars were marked at regular interval of 1m and taken for the manual bending. Manual bending was performed by moving them around a rigid pivot point and pressed which result in a 'V' shape non uniform bend. The dimensions after bending are reported in table no 1.

Table No.1 Result after manual bending operation of diameter 20 mm and 12 meter long TMT bar

Sample ID	Span at Ends - Ee (m)	Span at 1m from centre Ea(m)	Area (sq. m)	Bending Time (s)
TMT-M-01	1.850	0.6	10.3378	45
TMT-M-02	1.875	0.575	10.4775	44
TMT-M-03	1.900	0.55	10.6172	45
Average	1.875	0.575	10.4775	44.5

A 12 meter bar after 'V' bend has a span of 1.85 - 1.9 m at the end and very sharp angle at the bend. Area calculations shows that a single 'V' bent TMT requires 10.3125 sq.m floor space for storage. Around six labourers are required to presses a single bar of 20 mm cross section. A schematic sketch of V shape bend bar is given in the figure no.3a. Time required to manually bend the bar is about 44 to 45 s. This induces an excessive labour cost and poor packaging.

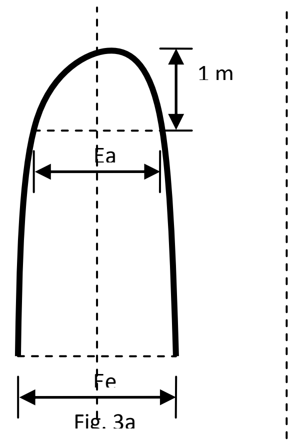

Figure 3a. A schematic sketch of V shape bend bar

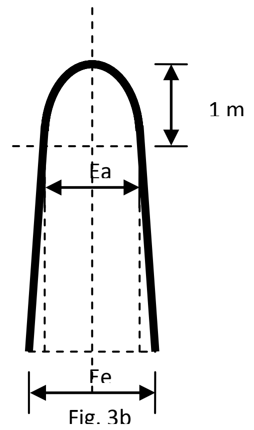

Figure 3b. A schematic sketch of U shape bend bar

B. *Uniform bending of the TMT bars*

These bars were bent using a mechanical bending machine which was designed and constructed in house as per the required bend specifications and other constraints. The bending machine is shown in figure no. 4. The bars were bent using a rotating disc with a pivot point and an anchor point. The disc rotates for about 250-270 degrees to give the TMT bars the required bend and also account for the shape regained by the spring back of the bar. This disc was also very high in weight which provides the required force to bend the TMT bars.

The disc was rotated with the help of a wire rope and a winch mechanism. The winch and rope provide the required torque to the disc to bend the TMT bars. Winch moves in the forward as well as the reverse direction. The winch derives its power from a 1:60 reduction gear box, the gear box in turn derives its power from a 1000 rpm motor. The selection of the motor, gear box, winch and the wire rope was done by calculating the loads required to bend the TMT and rotate the disc.

Table No.2 Result after machine bending operation of 20 mm TMT bar

Sample ID	Span at Ends- Ee (m)	Span at 1m from centre Ea (m)	Area (sq. m)	Bending Time (s)
TMT-N-01	0.7747	0.3302	2.4348	15
TMT-N-02	0.8001	0.3429	2.5201	15
TMT-N-03	0.7493	0.32766	2.3737	15
Average	0.7747	0.3335	2.4428	15

For this study the TMT bars were marked at regular interval of 1m and taken for the machine bending. The dimensions after bending are reported in table no 2. Area calculation shows that a single 'U' bent TMT requires 2.4-2.5 sq.m floor space for storage.

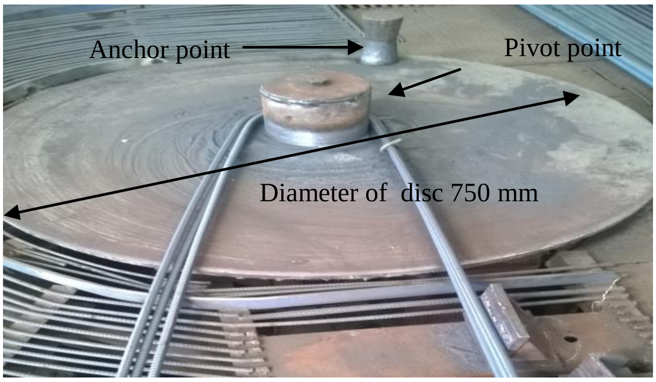

Figure 4. Bending machine

C. Cost saving

Industrial study for manual bending for dispatch of 300 Tons per day from 8 to 32mm diameter TMT bars, indicates the need of twelve workmen teams, each team consists of six workmen. Cost of manual bending per ton is Rs 50. For manual bending of 300 tons cost about 50x300 = 15000/- Rs per day. Hence the operation cost of bending for the month is 15000 ×30= 4,50,000/- Rs.

While in machine bending, Bending cost along with the operating cost is included. The cost of erection and subsequent commission of the machine was 5.5 lakh Rs. Operating cost include the electrical charges, mechanical maintence and the workmen wages. Industrial study shows the need of two teams of ten workmen and one operator each for the bending of 300 tons TMT bars. For machine bending of 300 tons, cost of workmen force = 22 x 480 = 10560/- Rs per day. Average maintence cost and electrical cost is about 200 Rs per day. Hence the operation cost of machine bending for the month is Rs 3,22,800/-. Hence the net saving per month is Rs 1, 27,200/.

V. DISCUSSION

The V bent TMT bars require 2.44 sq.m space while U bend TMT bars require 10.48 Sq. m space the storage of a bar. There is a saving of about 77% of floor space, which make the dealers and sellers comfortable to stock the product as it took less space to stock in their stock yards. The dealers and sellers of the product were also satisfied as this better packed product could be easily stored in their stock yards. Now larger amounts of TMT bars could be stored in same storage space proving to be more beneficial to the company.

The span of V bend TMT bars is about 1.875 m while for the U bend bars it is 0.77 m. There is a reduction of the span by about 57% by adopting 'U' bend TMT bars. This made the workers much more secured to load and unload the 'U' bend product as it has a smaller span than the 'V' bent TMT bars. This also gives good ergonomic grip by the workmen on the TMT bars. Figure 5 indicate the comparison between the manual and machine bending operation of the TMT bars.

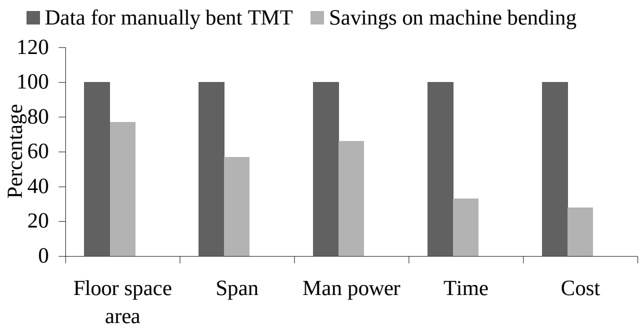

Figure 5. Comparison between the Manual and Machine bending operation

The TMT bars which were bent manually result in a 'V' shape rather than a much more uniform 'U' shape. The machine bent TMT renders the product a better bend quality which accounts for further improvement in the packaging of the product leading to a quicker dispatch and a overall increase in the goodwill of the company.

The time required for the machine bending is drastically reduced down as compare to the manual bending. The time required for bending of TMT bars is reduced by about 30 sec per 0.07 tons (i.e. 3 bars of 20 mm diameter). Hence automatic bending reduces the time of bending by about 33%.

The number of workers required for the three dispatch operations wiz. Bundling, bending and loading reduced drastically owing the installation of the in house manufactured bending machine. The installation of this machine also reduced the amount of physical work required to bend the steel TMT bars manually, decreasing the load on the workers and creating a safer work environment. As it is clear from the above results, that workmen force was reduced by 50 workmen with incorporation of the machine bending. There is a man power saving by about 66% by adoption of machine bending of TMT bars. The commissioning of the machine has imparted a better and safe environment during bending.

The calculation shows that the cost of the machine can be recovered in almost four to five months. The bending machine also helped in reducing the subsequent cost involved in packaging because of more uniform product which reduces the time of dispatch.

VI. CONCLUSION

The commissioning of the automatic bending machine led to a saving of about 77% in terms of floor space area. There is a reduction of the span by about 57% by adopting 'U' bent TMT bars over V bent TMT bars which ensure the safe loading operation.

The time required for the machine bending is drastically reduced by 33% as compare to the manual bending which enhances the productivity.

With adoption of machine bending of TMT bars, man power saving of about 66% was achieved as compared to manual bending.

The machine bending of TMT bars saves upto 28% cost over the manual bending operation. Further the machine and installation cost can be recovered within four to five months from the date of operation.

With the adoption of machine bending the uniform product quality was achieved which further increased the efficiency of the packaging and quicker dispatch. The commissioning of the machine has imparted a better and safe environment during bending.

VII. REFERENCES

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