CONCEPTUAL DESIGN OF HELICAL COILING MECHANISM FOR THE INTEGRATION OF ROLLING MILL

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Abstract

Circular bar of range of diameters is one of the significant products of rolling mill used for civil construction purpose. The reinforcement of construction work consists of longitudinal and transverse members. Transverse member is called as stirrup. According to the need of civil structure various shapes and sizes of stirrups are used for constructing the beams and columns. The stirrups are made manually or using semiautomatic machines at construction site or separate units are set up with automatic computer control machines. It is proposed to make stirrups at the last stand of rolling mill in the form of helical continuous coil instead of existing practices of stirrup making. Stirrups are cut from helical coil at construction site or continuous coil can be employed as a helical reinforcement. Existing engineering standards recommend use of continuous helical coil for the better strength. The work is aimed on conceptualizing a device, can be called as helical coiling mechanism, and integrating it with hot rolling mill. The efforts are made to access different alternative mechanisms which would be capable to work with the outlet conditions of bar of rolling mill. The bar coming out from the rolling mill is fed to the proposed mechanism for forming the helical coil. The suitable alternatives are discussed. The evaluation is done on the basis of merits and demerits for the selection of best suitable mechanism for the purpose. It is concluded that triple dowel mechanism out of six identified mechanisms would be best suited for the conceptual helical coil machine. The stirrup made by proposed technique achieves competitive advantages over existing stirrup making practices like the reduced handling of bar, hot rolled bars are bent into required sizes with less power along with good metallurgical and mechanical properties.

Keywords - *Stirrup, helical coil, coiling mechanism, integration, drum, dowel.*

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I. INTRODUCTION

Rolling mills are the backbone of development of modern world. Rolling mill is an automatic system or line of machines that performs both rolling and auxiliary operations - transport of the original billet from the stock to the heating furnaces and the mill rolls, transfer of the rolled material from one groove to another, turning, transport of the metal after rolling, cutting into sections, marking or stamping, trimming, packing, and conveyance to the stock of finished product. Manufacturing of the plain mild steel bar or torsional bar of various diameters is one of the products of rolling mill. These steel bars are used in civil construction. Concrete material is several times strong in compression but weak in tension. If a concrete block is subjected to shear stress, failure may occur by diagonal tension. To safeguard the concrete structure against such failure, reinforcement is required. This reinforcement is called shear reinforcement which is provided by the element called as stirrup or lateral-tie. Stirrup is one of the indispensable elements of reinforced cement concrete used for avoiding sagging of horizontal beam and buckling of vertical column along with the longitudinal member of it. According to need of shapes of columns and beams various shapes of stirrups are used such as rectangular, square, circular, triangular, hexagonal, etc. made out of, 8 mm, 10 mm, 12 mm either in plain mild steel or torsional steel[1]. Steel used for reinforcement is Fe 250, Fe 415, Fe 500 or equivalent grade of steel. Existing engineering standards recommend the use of continuous helical coil for better strength [9]. The stirrups are quite often made on construction site that to manually or using semiautomatic machines. The separate factories are also set up for manufacturing the stirrups by using fully automated computer control machines.

In this paper it is proposed that instead of taking a bar on construction site or in the factory for making stirrup, the bar can be bent in the form of continuous helical coil in hot condition. An attempt is made to conceptualize the helical coil forming mechanism, can be called as coiling mechanism. The bar coming out from rolling mill is fed to the coiling mechanism. Therefore, the speed of bar and high temperature are taken into account for devising the mechanism. The work is focused over making the circular continuous coil due to its simplicity in bending in the form of smooth curvature. Various concepts are proposed for attempting the problem. Evaluation of various concepts is done on the basis of their merits and demerits. Thoughtful process hints at many benefits on various fronts.

The stirrups can be cut at construction site from the helical coil or the same coil can be directly used as helical stirrup in the column. It would save power and time. Saving of manpower and space at construction site with high rate of production & accuracy are the additional benefits. It further eases handling of bars and helps to reduce the cost of shifting of bars from one place to another for making the stirrups. The muscular disorder of operator in manually stirrup making process can be eliminated. Wastage due to excess length of bar and scrap generation can be minimized or it can be eliminated by modifying the length of bar. The entire coil making process is carried out at elevated temperature thereby helping in maintaining the metallurgical and mechanical properties of material [10].

II. PRESENT SCENARIO OF MAKING STIRRUPS

Various methods are used for making stirrups. The manual process of making stirrups is extensively used in civil construction. In this process the specified MS round bar is cut as per required size of stirrup. The operator uses a wooden block as a platform for bending on which three nails are fixed, around which the banding takes place. The cut bar is passed horizontally between the nails up to the chalk mark and bends it using a lever. After completing one bend the operator lifts and reposition the bar for the next bending. In this way the operator makes all the required bends for making four corner stirrups.

Semiautomatic process is also developed by researchers. Vanalkar A.V.et.al., [3],[4],[6], designed & developed semiautomatic motorized stirrup making machine. The required length of bar is cut and placed in feeding mechanism which further push the bar to bending machine. With the help of cam and follower mechanism the number of require bends with specified angle are given to the bar for making the stirrup. This machine not only increases the production rate but also avoids the muscular disorder of the operator. Padole P.M., et. al.,[2,5], explained design & development of feeding mechanism for stirrup making machine. The researcher had developed stirrup making machine in which the feeding of stirrup wire was manual. It was essential to reposition the MS bar manually after getting the bend at desired position of same bar. For further automation author developed mechanized feeding system. A movable platform is designed, which is operated by stepper motor and also operated by d.c. motor. Analysis is carried out for both the systems and finally d.c. motor operated feeding mechanism is suggested. Viran Milani,et.al,[7] has designed and developed an automatic stirrup bending mechanism by using hydraulic principles and electronics. Researchers also introduced the automatic feeding mechanism for the pre-cut length of bar. A patent by Del. F. Marcello of United States on wire coiling process using mandrel is also noticed (1979) [8]. Fully automated machine controlled by computer is the latest generation machine for making the stirrups. The bar is fed to the machine from the roll of ms bar received from the rolling mill. A separate feeding mechanism is used. The program is prepared on computer for bending the straight MS bar along with length of side of stirrup or even any kind of shape of stirrup can be manufactured. This machine is versatile in nature as various shapes of stirrups can be made. The rate of production in manual stirrup making process is 50 stirrups per hour & around 150 numbers per hour in semiautomatic machine [3] where as fully automated machine produces more than 700 stirrups per hour.

2.1 Limitations in Present Methods of Making Stirrup

Existing stirrup making is the cold working process. Therefore it consumes more power. Sturdy and robust components are needed to sustain the reactions generated in bending. Essentially bar feeding mechanism is required which demands additional power. In cold working operation, hair cracks are developed on the outer surface of the bar which reduces the strength of stirrup. Residual stresses are developed in bar which further reduces the strength of the material. Shifting of bar from rolling mill to stirrup manufacturing unit and again to the construction site adds extra cost in manufacturing of stirrups.

III. CONCEPTUAL DESIGN FOR COILING MECHANISM

It is observed that the rollers of rolling mill push the bar. The bar coming out from the rolling mill can be fed to the coiling machine. The rollers of last stand of rolling mill for manufacturing the bars can be used as feeding mechanism of proposed coiling concept. Following aspects associated with moving bar are also viewed.

1. The motion of bar is linear and continuous.
2. The speed of bar is 3.6 to 4.0 m/s at the outlet of rolling mill
3. Temperature of bar is around 600^0C

Attempt is made for making circular helical continuous coil due to its simplicity in bending in the form of smooth curvature. High temperature of bar lowers down the yield point of material. High velocity provides the momentum to the bar. With due considerations of all these aspects, two types of mechanisms are put forth. One is the cylindrical drum mechanism and second one is dowel mechanism. The drum coil mechanism is as shown in Fig. 3.1.

3.1 Drum Coiling Mechanism

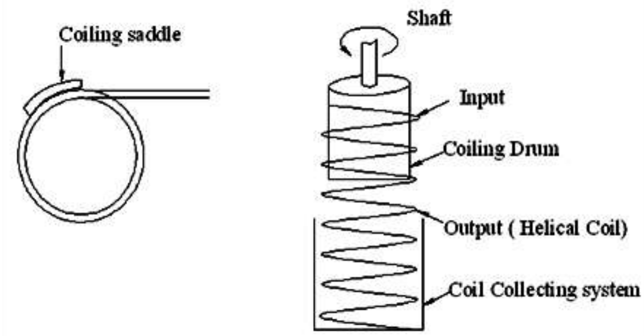

Fig. 3.1 Drum coiling mechanism

As shown in Fig. 3.1 the mechanism consists of circular cylindrical drum mounted on shaft at one end. The second end of the drum is kept free. The drum is coupled with actuator to synchronize the rotating speed with linear speed of bar coming out from rolling mill. The required speed and torque is obtained from power system and actuator. A saddle is kept over the surface with maintaining gap equal to the diameter of bar. The inner surface of saddle having curvature with the smooth helical groove to hold and guide the moving bar so that it turns over the curve surface and wound around the cylindrical drum. The helical coil forming over cylindrical drum comes out from free end of it. Coil collecting system kept below the drum collects the helical coil.

The cylindrical drum mechanism can be mounted in three different ways by positioning the axis of drum. Accordingly mechanism can be called as:-

i) Vertical drum coiling mechanism
ii) Horizontal drum coiling mechanism
iii) Inclined drum coiling mechanism

3.1.1 Vertical Drum Coiling Mechanism

The vertical drum coiling mechanism is as shown in Fig. 3.1 and described above. The axis of cylindrical drum is kept vertically. In this arrangement gravitational force of attraction helps to remove the coil from the drum surface. Feeding of bar is straight, simple and convenient.

3.1.2 Horizontal Drum Coiling Mechanism

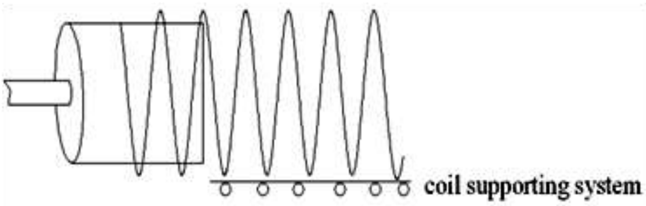

Fig. 3.2 Horizontal drum coiling mechanism.

The arrangement of horizontal drum coiling mechanism is as shown in Fig. 3.2. The coiling drum is kept horizontally. Extra arrangement is required for supporting the forming coil and removing it from surface of the drum. Similarly special arrangement is required for feeding the bar as rolling mill gives the straight and horizontal motion to the bar.

3.1.3 Inclined Drum Coiling Mechanism

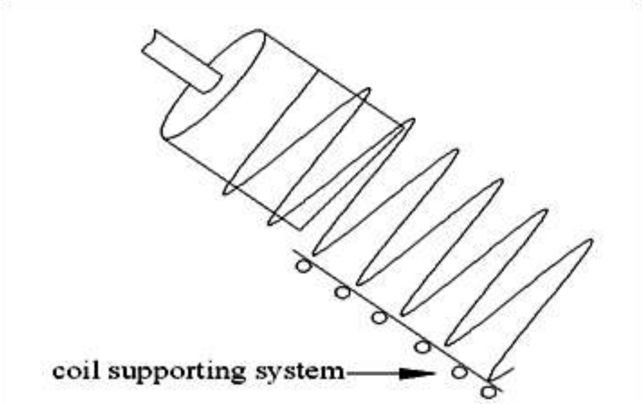

Fig. 3.3 Inclined drum coiling mechanism.

The mounting of coiling drum is shown in Fig. 3.3, in which axis of the drum is kept inclined to the horizontal plane. Considering the straight horizontal motion of bar coming out from rolling mill, feeding of bar can be made possible by changing the direction of helical groove of saddle. Similar to horizontal drum coiling mechanism the coil supporting and removing arrangement is needed, as shown.

3.1.4 Evaluation of Drum Coiling Mechanisms

The proposed various drum coiling mechanisms are evaluated and compared on the basis of various parameters and the feasibility of each one is taken into account which is illustrated in Table 3.1.

Table 3.1 Evaluation of drum coil mechanism

Parameter	Vertical drum coiling mechanism	Horizontal drum coiling mechanism	Inclined drum coiling mechanism
Feeding of M.S. bar.	Feeding is simple & convenient	Feeding of bar is complex.	Feeding is difficult & less convenient.
Removal of coil from surface of drum	Possible due to gravitational force. No additional mechanism would require.	Additional mechanism is highly required	Partial removal of coil is possible due to gravitational force. Additional mechanism is required
Mounting of drum on shaft	Cantilever mounting.	Cantilever mounting.	Cantilever mounting.
Additional load other than dead weight of drum	Marginal additional load on drive shaft would be added	Complete weight of coil would appear on drive shaft.	There is additional partial weight of coil on drive shaft.
Additional power requirement	Marginal additional power is required for forming the coil.	More power is required	Moderate power is required
Maintenance	Less	More	Moderate
Cost	Comparatively less than other two	More	Moderate

3.1.5 Selection of Drum Coiling Mechanism

From evaluation of proposed drum coiling mechanisms, it is observed that the vertical drum coil mechanism is more feasible and therefore it is selected for the further analysis.

3.2 Dowel Coiling Mechanism

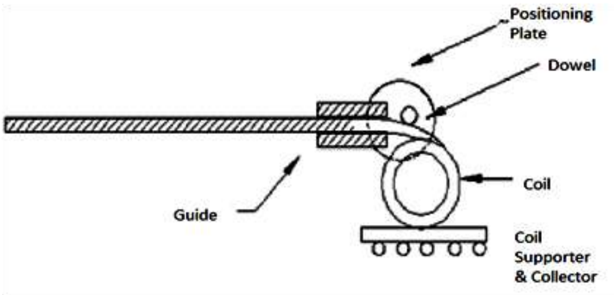

Fig: 3.4 Dowel coiling mechanism.

The arrangement of dowel coil mechanism is as shown in Fig. 3.4. It comprises with a bending pin, called as a dowel, mounted on base plate which provides the position to the dowel for pressing the bar. A guide is placed just near to the dowel for directing the motion of bar. The guide also provides a rigid support to the moving bar when dowel is positioned in the way of bar for pressing it. A gap between the dowel and rigid support is maintained. A bar has its own velocity and thus gaining momentum when it comes out from rolling mill. As soon as dowel acquires the position for pressing the bar, bending of bar is taking place. This bending is continued in motion of the bar causes the formation of continuous curvature results in coiling of the bar. This mechanism can be called as single dowel coiling mechanism. By changing the pressing distance the various diameter of coil can be obtained. The friction between fixed guide and moving bar is unavoidable where as the friction between dowel and bar can be minimize by mounting the roller on dowel. The coil supporter and collector system may be used for supporting and collecting the coil.

3.2.1 Double Dowel Coiling Mechanism

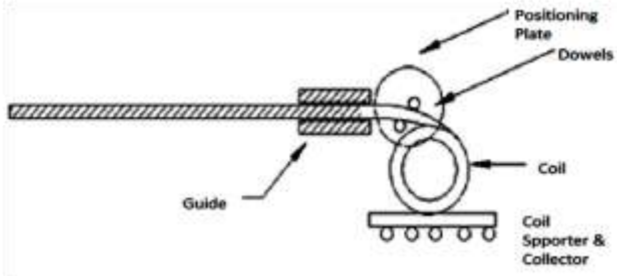

Fig: 3.5 Double dowel coiling mechanism.

In this proposal, instead of using single dowel two dowels are used, as shown in Fig.3.5. A guide is kept as it is. The functional requirement of guide is also same as in the previous concept. The second dowel is introduced on position plate along with first dowel for bearing the partial load of rigid guide. Rest of the operation for forming of the coil will remain same.

3.2.2 Triple Dowel Coiling Mechanism

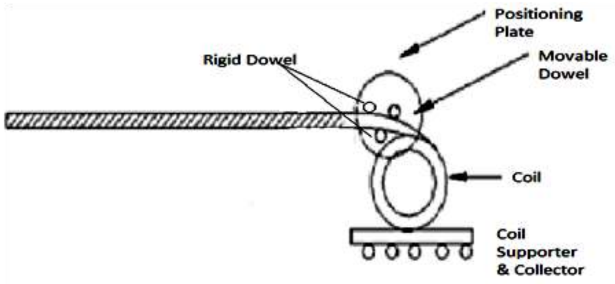

Fig. 3.6 Triple Dowel Coiling Mechanism

The concept of triple dowel mechanism is as shown in Fig. 3.6. In this arrangement rigid guide is replaced by third dowel. Two dowels near to rolling mill are rigidly mounted on positioning plate, where as one is vertically movable to press the moving bar for forming the various diameter of coil.

3.2.3 Evaluation of Dowel Coiling Mechanisms

The various design concepts of dowel coiling mechanisms are evaluated and compared on the basis of various parameters, which is illustrated in Table 3.1.

Table 3.2 Evaluation of dowel coiling mechanism

Parameter	Single dowel mechanism	Double dowel mechanism	Triple dowel mechanism
Feeding of bar	Simple	Simple	Simple
Friction between moving bar and member of coiling mechanism	More friction. Due to surface contact between bar and guide, friction between fixed guide and moving bar is very high operation.	Less friction. One dowel is used for pressing the bar where as second dowel is used for reducing the contact between guide and bar by bearing the load.	Very less friction. There is no fixed guide. By mounting the roller on dowel, friction between dowel and bar can be reduced to minimum.
Wear	More wear of guide therefore system may demand frequent replacement of guide.	Less wear offer less frequency of replacement of guide.	Wear is very less. All three dowels are rolling element.
Running Cost	More	Moderate	Very less

3.2.4 Selection of Dowel Coiling Mechanism

From evaluation of proposed drum coiling mechanisms, it is observed that the triple dowel coiling mechanism is more feasible and therefore it is selected for the further analysis.

IV. EVALUATION AND BEST SELECTION OF COILING MECHANISM

The various concepts of coiling mechanism are discussed. Amongst them the vertical drum coiling mechanism is selected from the group of drum mechanism where as triple dowel coiling mechanism is chosen from dowel mechanism. To select final best suitable mechanism the comparison is done as given in Table 4.1

Table 4.1 Comparison between vertical drum coiling mechanism and triple dowel coiling mechanism.

Sr. No	Vertical Drum Coiling Mechanism	Triple Dowel Coiling Mechanism
01	System is more complex	System is very simple
02	Extra power is required for rotating the drum for forming the coil.	Absolutely no extra power is required for forming the coil. The momentum of bar is used for it.
03	Need to maintain the extra accessories in the form of drums, shaft, saddle, actuator, etc	No extra accessories are required.
04	The various diameter of coil cannot be produced from same set of drum mechanism.	Various diameter of coil can be obtained from same set of mechanism.
05	To obtain the various diameter of coil, need to change the corresponding diameter of drums.	By changing the position of movable dowel any diameter of coil can be manufactured.
06	Initial and running cost is more	Both initial and running cost is very less
07	Maintenance cost is very high	Very less maintenance cost.

V. FINAL SELECTION OF MECHANISM

After evaluation of all above alternative mechanisms, it is found that the concept of triple dowel mechanism provides more advantages due to its versatility and simplicity.

VI. CONCLUSION

It is observed that the existing stirrup making practices are associated with many problems and is one of the bottlenecking operations in construction work.
Keeping in mind these problems, the conceptual helical coiling machine which would address the stirrup making problems in the form of circular helical coils. These helical coils would act as stirrups either in continuous form or can be cut as per requirement. In this paper, attempt is made to analyze various alternative mechanisms and it is found that triple dowel mechanism would be best suited for the application selected.

The proposed technique would address many issues which can be listed as follows

a) Integration of this machine with rolling mill will reduce handling of MS bars and associate labour cost.
b) Power requirement for making stirrups using semiautomatic or fully automatic machines can be minimize as operations are done at elevated temperature.
c) Manual stirrup making practices can be eliminated and therefore the problem of muscular disorder can be avoided.
d) Requirement of skilled labour for making stirrup on site would be eliminated.
e) Space at construction site and time can be saved.
f) Most important aspect is the mechanical strength and metallurgical properties of the helical coil stirrups manufacturing by proposed coiling mechanism would be far better compared to existing practices.

Keeping in mind the advantages, it can be concluded that conceptual coiling machine would revolutionize the stirrup making practices and would be first proactive step to improve the quality and productivity of construction work.

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