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Parametric Study on Cross-Sectional Behavior of Trapezoidal Section to Transverse the Bending Effect of Rollers Used in Rolling Mill

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Abstract— In this research article the cross sectional behavior of trapezoidal section to minimize the bending effect of deflection of rollers used in rolling mill is to be studied. In the first part, stress arises in the counter effect of simple rectangular section to minimize the upper bending is calculated. Stresses come out after attachment of rectangular section should be minimize to reduce down its lower adjacent length. This reduction in lower length gives the trapezoidal shape of overall cross section. The calculated value and graph of the change in lower length of rectangular section gives the formation of trapezoidal section which would more effective as compared to the previous rectangular section. Values for stress, strain and module of elasticity were calculated at three different points on the middle surface of roller and it is carried out theoretically. Further the mathematical model is to be generated for making the proper way of calculation. The remaining comparison in between different section of rectangle and trapezoidal is measure and the effective design of section is to be proceed to maximize the efficiency of rollers.

Keywords—Rectangular Section, Trapezoidal Section, Rollers, Stresses, Design of Section.

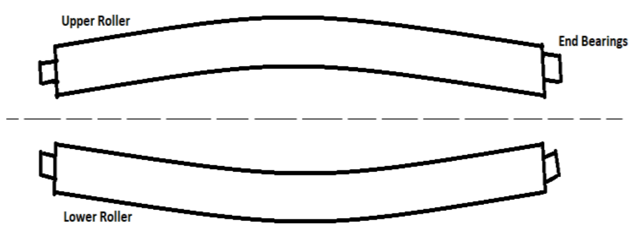
I. INTRODUCTION

A parameter is defined as a numerical or other measurable factor forming one of a set that defines a system or sets of conditions of its operation. Parameters are elements of a system that are useful or critical to identifying a system or evaluating a system's performance, status, or condition. As an example, parameters of an equation modeling movement could include the mechanics, masses, dimensions and shapes, and densities and viscosities of fluids within the system.

A parametric analysis, also known as a sensitivity analysis, is the study of the influence of different geometric or physical parameters or both on the solution of the problem. Parametric analysis is an important tool for design exploration, for instance, to examine the influence of the air gap length on the magnetic force in a contactor. Altair's simulation suite offers engineers and designers a range of parametric analysis tools for a variety of use cases. The analysis scenario can be single or multi-parametric including the parameter time, and/or geometric or physical parameters. Altair users can perform parametric studies based on fluids and thermal performance, electromagnetics, motion, vibrio-acoustics, structures, and more. Metal forming procedures are divided into two types: bulk metal forming and sheet metal forming. External force is applied to a sheet to adjust its geometry to the required shape in sheet metal forming procedures. The material deforms plastically as a result of the applied force. Bending, deep drawing, stretching, and rolling are some of the sheet metal forming processes that have been created. One of the sheet metal manufacturing processes is roll forming. This procedure, also known as contour-roll forming or cold-roll forming, is used to continually form sheet metals into the appropriate shape. The metal strip is bent in stages after the initial blank passes through a set of driven rolls. The created strip is then sheared and stacked into appropriate lengths. The thickness of the sheet is normally between 0.125 and 20 mm. typically, the forming speed is less than 1.5 m/s. Dimensional tolerances and spring back are two major factors to consider while creating the shape and sequencing of the rolls. The rollers are often composed of carbon steel or grey iron, and they may be chromium plated to improve the surface polish and prevent wear [1]. Parametric analysis is based on user-defined solving scenarios, producing “unrefined” solutions. These results need to post-process in order to find the optimal solution or compromise in an overall design.

II. MATERIALS AND METHODS

The goal of this study was to look at how different parameters affected the absorber tubes of steel rod in a trapezoidal cavity receiver. The configuration was a trapezoidal cavity that encircles a four parallel rod batch. Previously, scientists had looked into this cavity receiver for a linear rectangular roads. The effect of the rectangular rods reflecting the stress parameter in sections and selective surface rolling on the two opposite rods was studied and compared to its thermal



performance.

Figure 1: Reverse bending effect on both side of rollers

The cavity angle and rod size impacts were examined in

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different models to determine the failure rate and frictional heat loss. Determined the temperature obtained by absorber rods at a specific time and location, and developed an optimize and proper trapezoidal section for a transverse effect of roller bends in rolling machine [2]. Regular rectangular plates or beam models were employed in the above-mentioned adaptive structure investigations. Structures like trapezoidal wings and wind turbine blades, on the other hand have a changeable cross-section. The cross-section structure of composite materials has been researched and analyzed only a few times to far. In this paper, the trapezoidal composite section is used as the research object. The load on the thin plate can be split into in-plane load and load perpendicular to the in-plane direction using the force superposition principle. The bending problem of composite laminates is solved in this work. The laminate's shape changes from rectangular to trapezoidal, and the laminates' border conditions differ.

The semi-inverse technique, series method, variation method, and other methods are often used to find the analytical solution of laminate deformation. It is challenging to assume the solution form that fulfils the displacement boundary conditions for the bending issue of trapezoidal laminate using the semi-inverse approach and series method. It is also challenging to develop an appropriate series solution form that meets various displacement boundary requirements for variation methods such as the Rayleigh–Ritz method. In the Galerkin technique, it is difficult to define the virtual work of the approximation inaccuracy between the approximate deflection surface function and the balance equation, in addition to selecting the deflection surface series. The Kantorovich technique, on the other hand, has distinct advantages in the solution of a wide range of deformation issues. This method not only easily obtains the deformation of a normal rectangular plate, but also facilitates the coordinate transformation to be suited for the trapezoidal laminate, according to the study. It can also be used with a variety of displacement boundary conditions. To tackle the problem, the Kantorovich approach and the idea of minimum potential energy were adopted.

III. MATHEMATICAL MODELING

Advanced materials processing of nano composites by solid state mechanical alloying entails a greater number of process parameters in the design section, necessitating the development of various modelling and optimization methodologies. The goal of this study is to look at a variety of linear and non-linear mathematical methodologies, such as dimensional analysis using Buckingham's π-theory, regression analysis, and a hybrid approach [4].

Dimensional analysis, which is also a novel mathematical tool, can be used to model the physical quantities that influence system behavior responses. The experimental work may be described using this way, and the system behavior can then be anticipated. The definition of Buckingham π theorem demonstrates the linking of all the process variables into number of π-terms which are dimensionless quantities. The mass (M), length (L), and time (T) are the fundamental dimensionless quantities. Here, total variables are 7 (i.e. n) and fundamental dimensions are 3 (i.e. m) so that there will be 4[i.e. (n - m)] π terms [4].

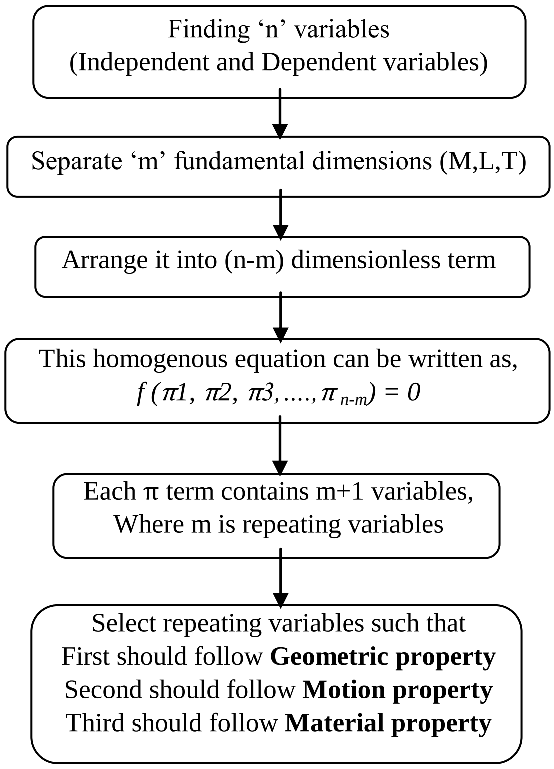
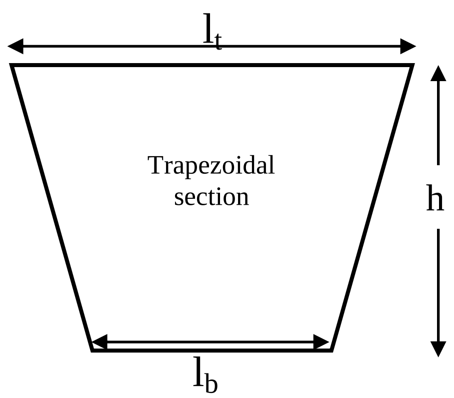


Figure 2: Flowchart showing the implementation of modeling approach for predicting the system behavior

Table 1: Dimensions and Design data used in section

Design Parameter	Symbol	Unit	Dimension
Stress	σ	N/mm^2	$[M^1,L^{-1},T^{-2}]$
Force	F	N	$[M^1,L^1,T^{-2}]$
Diameter of rods	d	mm	$[L^1]$
Velocity of roller	v	mm/sec	$[L^1,T^{-1}]$
Density of Material	ρ	Kg/mm^3	$[M^1,L^{-3}]$
Height of Trapezium	h	mm	$[L^1]$
Lower length of rod	l	mm	$[L^1]$



Where,

l_b is the bottom length or lower length of Trapezoidal section,

l_t is the top length of Trapezoidal section and 'h' is the height of Trapezoidal section. Hence, the relationship of π-term can be written as dimensionless equation for reducing stress (σ) is as follows,

$$\sigma = f(d, v, \rho, F, h, l)$$

According to Buckingham π theorem, fundamental dimensions exist in diameter (d), velocity (v) and density of rod material (ρ). These three dimensions do not form any dimensionless group. Therefore, functional relationship for π term can be expressed as,

$$f(\pi 1, \pi 2, \pi 3, \pi 4) = 0$$

Solving π1 term, $\pi 1 = d^{a1}, v^{b1}, \rho^{c1}, F$

By the principle of dimensional homogeneity,

$$\pi 1 = d^{a1}, v^{b1}, \rho^{c1}, F$$

$$[M^0, L^0, T^0] = [(L)^{a1}, (LT^{-1})^{b1}, (ML^{-3})^{c1}, (MLT^{-2})]$$

$$[M^0, L^0, T^0] = [(M)^{c1+1}, (L)^{a1+b1-3c1+1}, (T)^{-b1-2}]$$

On equating we get,

c1+1 = 0, a1+b1-3c1+1 = 0, -b1-2 = 0

a1 = -2, b1 = -2, c1 = -1

By substituting these values in π1 term, we get

$$\pi 1 = d^{-2}, v^{-2}, \rho^{-1}, F$$

$$\pi 1 = F/(d^2.v^2.\rho)$$

Solving π2 term, $\pi 2 = d^{a2}, v^{b2}, \rho^{c2}, h$

By the principle of dimensional homogeneity,

$$\pi 2 = d^{a2}, v^{b2}, \rho^{c2}, h$$

$$[M^0, L^0, T^0] = [(L)^{a2}, (LT^{-1})^{b2}, (ML^{-3})^{c2}, (L)]$$

$$[M^0, L^0, T^0] = [(M)^{c2}, (L)^{a2+b2-3c2+1}, (T)^{-b2}]$$

On equating we get,

c2 = 0, a2+b2-3c2+1 = 0, -b2 = 0

a2 = -1, b2 = 0, c2 = 0

By substituting these values in π2 term, we get

$$\pi 2 = d^{-1}, v^0, \rho^0, h$$

$$\pi 2 = h/d$$

Solving π3 term, $\pi 3 = d^{a3}, v^{b3}, \rho^{c3}, l$

By the principle of dimensional homogeneity,

$$\pi 3 = d^{a3}, v^{b3}, \rho^{c3}, l$$

$$[M^0, L^0, T^0] = [(L)^{a3}, (LT^{-1})^{b3}, (ML^{-3})^{c3}, (L)]$$

$$[M^0, L^0, T^0] = [(M)^{c3}, (L)^{a3+b3-3c3+1}, (T)^{-b3}]$$

On equating we get,

c3 = 0, a3+b3-3c3+1 = 0, -b3 = 0

a3 = -1, b3 = 0, c3 = 0

By substituting these values in π3 term, we get

$$\pi 3 = d^{-1}, v^0, \rho^0, l$$

$$\pi 3 = l/d$$

Solving π4 term, $\pi 4 = d^{a4}, v^{b4}, \rho^{c4}, \sigma$

By the principle of dimensional homogeneity,

$$\pi 4 = d^{a4}, v^{b4}, \rho^{c4}, \sigma$$

$$[M^0, L^0, T^0] = [(L)^{a4}, (LT^{-1})^{b4}, (ML^{-3})^{c4}, (ML^{-1}T^{-2})]$$

$$[M^0, L^0, T^0] = [(M)^{c4+1}, (L)^{a4+b4-3c4-1}, (T)^{-b4-2}]$$

On equating we get,

c4+1 = 0, a4+b4-3c4-1 = 0, -b4-2= 0

a4 = 0, b4 = -2, c4 = -1

By substituting these values in π4 term, we get

$$\pi 4 = d^0, v^{-2}, \rho^{-1}, \sigma$$

$$\pi 4 = \sigma/v^2\rho$$

Now, The functional relationship for π term can be expressed as,

$$f(\pi 1, \pi 2, \pi 3, \pi 4) = 0$$

$$f[(F/(d^2.v^2.\rho)), (h/d), (l/d), (\sigma/v^2\rho)] = 0$$

$$(\sigma/v^2\rho) = f[(F/(d^2.v^2.\rho)), (h/d), (l/d),]$$

To remove the function of above model we should insert the universal value which is approaches to the stress formula of the design. Area is one of the important factor to determine the stresses in the rod section of trapezium. So we put the square of 'π/4' term to balance the equation.

$$(\sigma) = [(F/(\pi^2 d^2/16)), (h/d), (l/d),]$$

$$(\sigma) = F.h.l/(\pi d^2/4)^2$$

$$\boxed{(\sigma) = F.h.l/A^2}$$

The above mathematical model formula should be used to determine the stresses in the bottom rod of the trapezoidal section. The results obtained from the parametric investigations are in line with the established conclusions, indicating that the developed model maps the flow phenomenon of stress from rectangular to trapezoidal section very well.

IV. Results and Discussion

For rectangular and trapezoidal channel sections, parametric research were also carried out to establish the dependence of depth ratio on various factors.

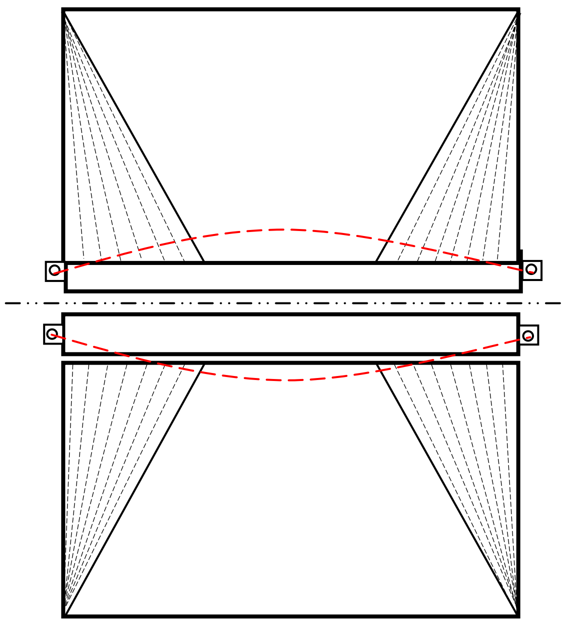
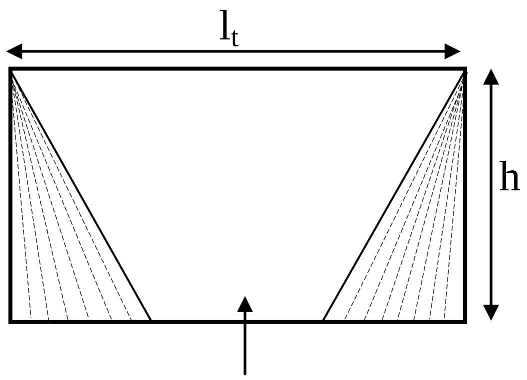


Figure 3: Conversion of Rectangular section into Trapezoidal section to transverse the bending effect of rollers used in rolling mill

As in the above diagram the rollers are supported with end bearings. There are two rollers upper roller and lower roller used to minimize the thickness of raw materials inserted into the gap of these two rollers used in rolling mill. But many of the time the rollers are deflected towards away from each other because of the intensity of raw materials. Hence the number of passes is increases into the rollers which will affect the production rate of industry. To overcome these effect of bending one rectangular section should be attach on both side of roller to transverse the effect of deflection in rollers. When rectangular section imposed the maximum stress at its end point which are connected to the outer surface of the rollers, it will approach to its failure point and thus the lower length of the rod is minimize to reduce the stress at corner points of rectangle. So the calculation part are arise to optimize the design of trapezoidal section. This trapezoidal section is made with steel materials having property SAE 1030. It is readily available in any market areas. The upper portion and lower portion both are attached with nut bolts for getting flexible maintenance to machine from industry workers. Red colour dotted line shown in the figure no. 3 the deflection feature when raw materials is inserted inside the gap of upper and lower rollers. Maximum stresses are arise at the end point of bearings. It will affect the life of bearing and the replacement period of bearing is increases.



Let,

F be the applied force acting on trapezium section, N.

h be the height of the trapezium section, mm.

l_t be the top length of trapezium section, mm.

σ be the stress induced at bottom corner and adjacent two rods of trapezium, N/mm^2 or MPas..

A = πd^2 , Cross sectional area of bottom rod mm^2 and

l_b be the bottom length of trapezium section, mm.

The experiment is conducted in T-24/A, Yawalkar Rolling Mill, MIDC Hingna, Nagpur-440016. It's MSME (Micro, Medium and Small Enterprise) Company. The maximum applied load 'F' is around 900N as per the specification given from company and the diameter of rod is 280mm.

Table 2: Variation in bottom length of trapezium section at constant height of 1000mm

Sr. No.	'l_b' Bottom length	Stress induced 'σ'
1.	1500 mm	0.35 MPas
2.	1300 mm	0.31 MPas
3.	1100 mm	0.26 MPas
4.	900 mm	0.21 MPas
5.	700 mm	0.16 MPas
6.	500 mm	0.11 MPas
7.	300 mm	0.07 MPas
8.	100 mm	0.02 MPas

After Minimizing the bottom length of trapezium section the stress induced is also decrease. But it does not show the optimum point at which we should stop to minimize the bottom length dimension. So for that purpose we have to do another analyses in ABAQUS software because practically it is not possible to take sharp edge point at lower portion of trapezium section [7]. ABAQUS FEA is a software suite for finite element analysis and computer aided engineering. In this software we vary the bottom length from 0 mm to 400 mm and check the stress phenomenon at the centre portion of the rollers.

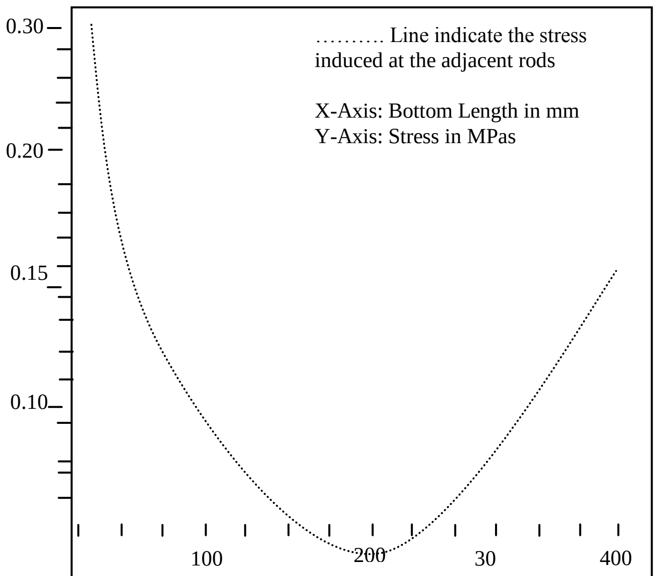


Fig. 3. Stress induced at the surface of roller rods with a variation in bottom length

With the help of above graph it is clear that the bottom length dimension is optimize to 200mm.

Table 3: Variation in height of trapezium section at constant bottom length of 200mm

Sr. No.	'h' height	Stress induced 'σ'
1.	100 mm	4.74 KPas
2.	300 mm	14.24 KPas
3.	500 mm	23.73 KPas
4.	700 mm	33.23 KPas
5.	900 mm	42.72 KPas
6.	1100 mm	52.22 KPas
7.	1300 mm	61.71 KPas
8.	1500 mm	71.21 KPas

After minimizing the adjusting the height of trapezium section the stress induced is also vary. But it does not show the optimum point at which we should stop to minimize the height dimension. So for that purpose we have to do another analyses by using Maximum deflection formula because practically it is not possible to take up the centre maximum deflection effect in between V shape of adjacent rods of trapezium section [8].

$$\delta = (FL^3)/48EI$$

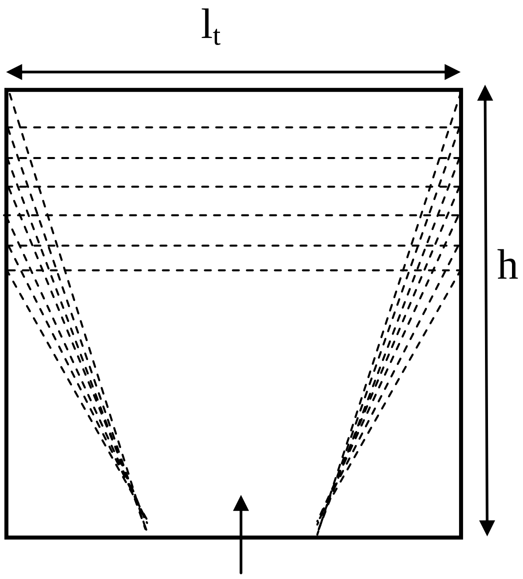
Where,

δ be the maximum deflection at centre of lower bottom rod.

E is the modulus of elasticity (N/mm^2) and I is the area moment of inertia (mm^4). From Design Data book of B. D. Shewalkar at Pg. no. 39, The value of E = 204 N/mm^2 and I = 301.71 x 10^6 mm^4 for SAE 1030 material. Now, put the value of 'F' in this deflection equation as we have derive in mathematical models.

$$\delta = (\sigma A^2L^3)/48EIhL$$

$$\boxed{\delta = (\sigma A^2L^2)/48EIh}$$



To determine the optimum height of the trapezium, the variation in the height with respect to the maximum deflection at the bottom length of trapezoidal section is optimize in following table no. 4. In this table the average value of stress induced inside the rod is taken to acquire the optimum value of height of trapezoidal section.

Average stress induced,

σ = (4.74+14.24+23.73+33.23+42.72+52.22+61.71+71.21)/8

σ = 37.97 KPas.

Table 4: Variation in height of trapezium section with respect to Max. Deflection at the centre of bottom length

Sr. No.	'h' height	Max. Deflection 'δ'
1.	100 mm	0.019 mm
2.	300 mm	6.497 x 10^{-3} mm
3.	500 mm	3.898 x 10^{-3} mm
4.	700 mm	2.784 x 10^{-3} mm
5.	900 mm	2.165 x 10^{-3} mm
6.	1100 mm	1.772 x 10^{-3} mm
7.	1300 mm	1.499 x 10^{-3} mm
8.	1500 mm	1.299 x 10^{-3} mm

The middle area of the trapezoidal cross-section sample had the highest mean stresses. Those stresses have higher values than stresses in a cuboidal sample. Low values of stresses in the sample corners indicate that they are not involved in the creation of reaction forces that oppose the inertia forces of the lowering platen; as a result, only the middle section of the sample reacts effectively to platen movement. The bow height grows as the distance from reference edge A is increased. The distance from the edge has little influence on the hole's modality, although bowing has risen.

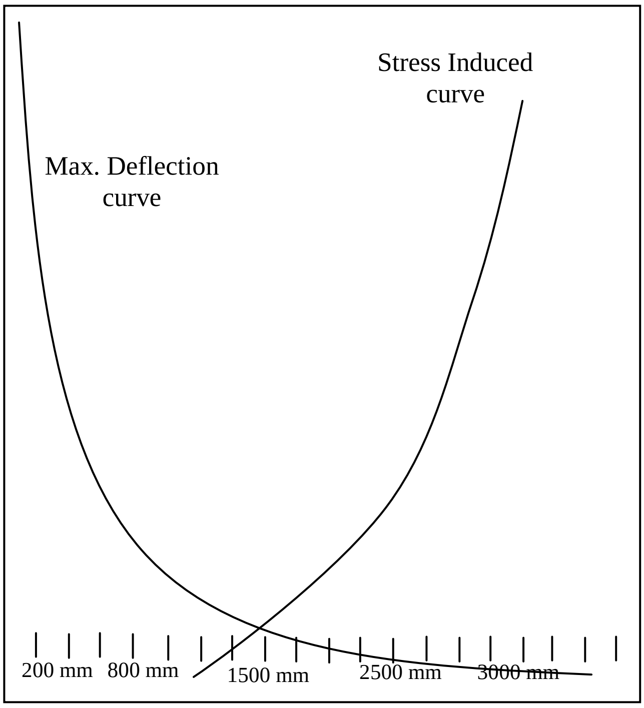


Figure 4: Intersection of optimum point at which the height of trapezoidal section is determined

Each calibration represent the 200mm height of trapezoidal section. Height of Trapezoidal Section from top rod to bottom rod is determined with the help of above graph and it is found to be 1500mm.

V. CONCLUSION

In this research, the strength of trapezoidal section corrugated by converting it from rectangular section to trapezoidal section been studied. When the vertical load applied on the center of the lower bottom rod it results in compression in upper roller and tension in lower roller of the section. Trapezoidal section supports member to stay straight whereas the compression rollers tries to deflect laterally from its original position. From the above results, we can conclude that the bottom length should be 200mm and height is 1500mm. The cross sectional behavior is affected by the distance between the rollers of the section and location at an application of load. From the above results, we can interpret that converting supporting section as a trapezoidal section will transverse the effect of bending at the centre of the rollers.

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