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DESIGN AND DEVELOPMENT OF PRE-FORM WIRE ROPE FIXTURE

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ABSTRACT

The advancement in technologies and vast industrial progress has led the industries to focus on process improvement rather than justifying the quantity-based processes. The process improvement stresses on focusing on minor parameters of the components which are thus responsible for better quality of the final product. For such quality based process improvement design of newer fixtures for work handling purposes is very necessary. A fixture can be designed for the particular job using production tools which make the standard machine tools more versatile to work as specialized machine tools. In machining fixtures, minimizing workpiece deformation due to clamping and cutting forces is essential to maintain the machining accuracy. The various methodology used for clamping operation used in different application by various authors are reviewed in this dissertation. Fixture is required in various industries according to their application. This can be achieved by selecting the optimal location of fixturing elements such as locators and clamps. The fixture set up for component is done manually. For that more cycle time required for loading and unloading the material. So, there is need to develop system which can help in improving productivity and time. Fixtures reduce operation time and increases productivity and high quality of operation is possible.

KEYWORDS: Pre-form, Fixture, Ferrule, Roller, Rope.

INTRODUCTION

The wire ropes have wide range of applications in industries as well as domestic purpose. This topic is under research in recent years; to improvising the quality and stability of wire-ropes. The advancement in technologies and vast industrial progress has led the industries to focus on process improvement rather than justifying the quantity-based processes. The process improvement stresses on focusing on minor parameters of the components which are thus responsible for better quality of the final product. For such quality based process improvement design of newer fixtures for work handling purposes is very necessary. A fixture can be designed for the particular job using production tools which make the standard machine tools more versatile to work as specialized machine tools.

The project focuses on designing a fixture for improvising the wire-rope manufacturing process.

Problem Statement

The wire-ropes are used in various applications including heavy load lifting or holding, hence there should be no room for error.

The wire ropes formed may contain extraordinary strain although we have conformed the preforming and post forming processes. The main genesis of strain is due to vibration and wobbling of wires during the twisting operation. The wires are being twisted and rounded on one wire at middle. During this operation the moving wires get wobbled and deflected from its original path. It affects the product making it prone to internal stresses and undesired cross-section area distribution of wire. This may advocate the breakage of the wire-ropes during application.

So as to reduce the strain and uneven distribution of cross-section area of wire we introduced the wire rope fixture.

Fixtures

A fixture is a work-holding or support device used in the manufacturing industry. Fixtures are used to securely locate (position in a specific location or orientation and support the work, ensuring that all parts produced using the fixture will maintain conformity and interchangeability. Using a fixture improves the economy of production by allowing smooth operation and quick transition from part to part, reducing the requirement for skilled labor by simplifying how workpieces are mounted, and increasing conformity across a production run. A fixture differs from a jig in that when a fixture is used, the tool must move relative to the workpiece; a jig moves the piece while the tool remains stationary.

Purpose

A fixture's primary purpose is to create a secure mounting point for a workpiece, allowing for support during operation and increased accuracy, precision, reliability, and interchangeability in the finished parts. It also serves to reduce working time by allowing quick set-up, and by smoothing the transition from part to part. It frequently reduces the complexity of a process, allowing for unskilled workers to perform it and effectively transferring the skill of the tool maker to the unskilled worker. Fixtures also allow for a higher degree of operator safety by reducing the concentration and effort required to hold a piece steady.

Economically speaking the most valuable function of a fixture is to reduce labour costs. Without a fixture, operating a machine or process may require two or more operators; using a fixture can eliminate one of the operators by securing the workpiece.

Wire-Rope Failures

Under working conditions, failures are observed in wire ropes. The failures are mainly caused due to the defects formed by unequal stressing of wire ropes. The strands of wires which combine to make the wire rope should be equally stressed. The unequal stressing of the strands leads to reduction of the tensile strength of the individual strands. When put to use under low load applications these ropes work fine, but when the wire ropes are subjected to heavier applications, the weaker strands are first to break. This greatly reduces the tensile strength of the rope. When the weaker strand breaks the total load falls on the other strands thus reducing their combined strength. The breakage also leads to distortion of the cross-section of the wire, causing unequal stress flow. Therefore, these factors are mainly responsible for failure of the wire ropes in high end applications. The below picture shows a failed wire rope due to unequally stressed wire strands.

Manufacturing Process

There are many conventional methods for manufacturing wire ropes.

In order to increase and maintain the accuracy of the wire rope there are two types of processes.

- Pre forming
- Post forming

Pre forming

Pre-forming process are those processes which are done on wire ropes before the twisting of wires on one another. It includes vibration control, equal stressing of the strands, uniformity of the cross-section, stress reduction facilities.

Post Forming

These are the processes are done on wire-ropes after the wire ropes are twisted in the required form. There main purpose is to increase the corrosion resistance and reduce the internal stresses confronted during the manufacturing of wire ropes.

Calculations

Analytical calculations for determining the diameter of the center shaft

The calculations are done to prove that the diameter of the shaft falls in the safer limits. The dimensions of the plates are decided from the software simulations on a trial and error basis.

Front plate

Volume = Volume of plate – Volume of hollow cylinder

$$= [(1/3) \times \pi(r_1^2 + r_1 r_2 + r_2^2)] - [(\pi/4) \times d^2 \times t]$$

$= [(1/3) \times \pi(r_1^2 + r_1r_2 + r_2^2)] - [(\pi/4) \times 42^2 \times 25]$

$= 1.95113 \times 10^{-4} - 3.4636 \times 10^{-5}$

$= 1.60477 \times 10^{-4}\ m^3$

Mass = $\rho \times g \times V$

$= 7800 \times 9.81 \times 1.60477 \times 10^{-4}$

= 12.3 N

Mass of threaded shaft = 7.8 N

Therefore, total mass of front plate = 12.3 + 7.8 = 20.1 N

Middle plate

Vol = $\{[(\pi/4) \times 130.4^2 \times 25]+[(\pi/4) \times 72^2 \times 69]+[(\pi/4) \times 58^2 \times 40]\}- [(\pi/4) \times 48^2 \times 134]$

$= 4.8 \times 10^{-4}\ m^3$

Mass = $\rho \times g \times V$

$= 7800 \times 9.81 \times 4.8 \times 10^{-4}$

= 36.8 N

Design of the center shaft

S_{yt} = 220.594 N/mm^2

Diameter of Front plate (d_f) = 110 mm

Diameter of Middle plate (d_f) = 130.4 mm

$K_b = 2$, $K_t = 1.5$ - As per ASME code

$\tau_{allowable} = 0.3 \times S_{yt}$

$\tau_{allowable} = 0.3 \times 220.594 = 66.2$ N/mm^2

* Torque to be transmitted (T) = F x (d/2)

For front plate, T_f = 100 x (110/2) = 5500 N.mm

For middle plate, T_m = 100 x (130.4/2) = 6520 N.mm

Therefore, Resultant (T) = 8530 N.mm

* Max. Bending moment

Support reaction (R_A) = 20.1 N + 36.8 N = 56.9 N

Bending moment at A = 0 - Fixed

Bending moment at Middle plate = 101 x 56.9 = 5746.9 N.mm

Bending moment at Front plate = (146 x 36.8) + (247 x 56.9) = 19427.1 N.mm

Therefore, Max. Bending moment = 19427.1 N.mm

* Calculations of the Diameter

$[(\pi/4) \times d^3 \times \tau_{allowable}] = \sqrt{[(M \times K_b)^2 + (T \times K_t)^2]}$

$[(\pi/4) \times d^3 \times 66.2] = \sqrt{[(19427.1 \times 2)^2 + (8530 \times 1.5)^2]}$

$d^3 = 786.77$

d = 10 mm - rnd. Off

Diameter of the hollow section (d_o) = d/2 = 5 mm

The actual dimensions for the shaft decided are d = 28 mm and d_o = 14 mm provide space for fitting of the threaded shafts and for the provision of the middle plate and the front plate. The dimensions are under the safe limits and therefore, are acceptable.

Software Simulation

Study Properties

Study name	Static Analysis
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from Solid works Flow Simulation	Off
Solver type	FFEPlus
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Mesh Properties

Mesh type	Solid Mesh
Mesher Used:	Curvature-based mesh
Jacobian points	4 Points
Maximum element size	24.5253 mm
Minimum element size	4.90506 mm
Mesh Quality	High
Re-mesh failed parts with incompatible mesh	Zero

6.3. Mesh Information Details

Mesh type	Solid Mesh
Mesher Used:	Curvature-based mesh
Jacobian points	4 Points
Maximum element size	24.5253 mm
Minimum element size	4.90506 mm
Mesh Quality	High
Re-mesh failed parts with incompatible mesh	Zero

6.4. Material Properties

1. Material for fixture body

Name: AISI 4340 Steel, normalized

Model type : Linear Elastic Isotropic

Yield strength : 7.1e+008 N/m^2

Tensile strength : 1.11e+009 N/m^2

Elastic modulus : 2.05e+011 N/m^2

Poisson's ratio : 0.32

Mass density : 7850 kg/m^3

Shear modulus : 8e+010 N/m^2

Thermal expansion coefficient: 1.23e-005 /Kelvin

2. Material for Pins and Rollers

Name : Tn-3Al-8V-6Cr-4Mo-4Zr

Model type : Linear Elastic Isotropic

Yield strength : 1.03421e+009 N/m^2

Tensile strength : 1.22e+009 N/m^2

Compressive strength : 1.09e+009 N/m^2

Elastic modulus : 1.04e+011 N/m^2

Poisson's ratio : 0.33

Mass density : 4820 kg/m^3

Shear modulus : 4e+010 N/m^2

Thermal expansion coefficient: 8e-006 /Kelvin

Static Stress-Strain Analysis

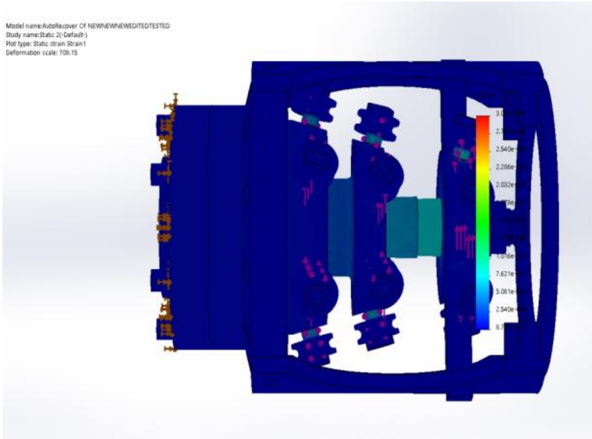


Fig: Static Stress-Strain Analysis.

Nodal stress-strain analysis

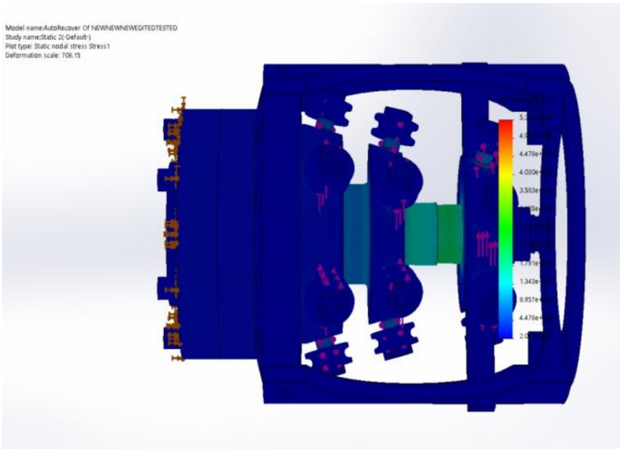


Fig: Nodal stress-strain analysis.

Static analysis for factor of safety distribution analysis

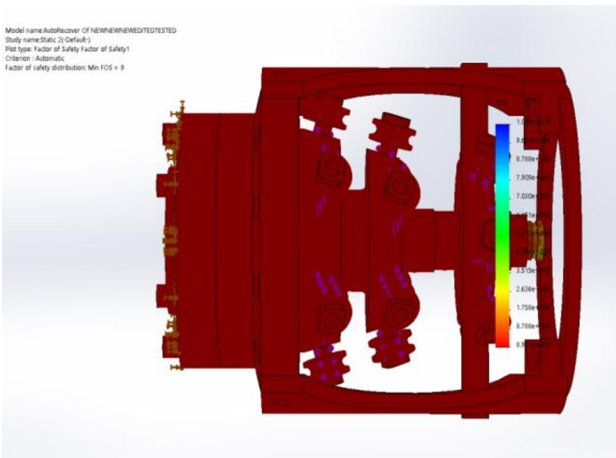


Fig: Static analysis for factor of safety distribution analysis.

Design Insight analysis

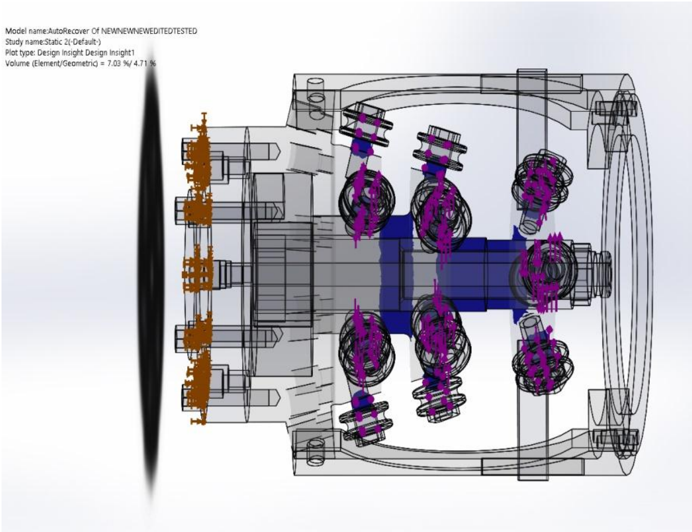


Fig: Design Insight analysis.

Design and Cevelopment of the Fixture

Fixtures must always be designed with economics in mind; the purpose of these devices is to reduce costs, and so they must be designed in such a way that the cost reduction outweighs the cost of implementing the fixture. It is usually better, from an economic standpoint, for a fixture to result in a small cost reduction for a process in constant use, than for a large cost reduction for a process used only occasionally.

Most fixtures have a solid component, affixed to the floor or to the body of the machine and considered immovable relative to the motion of the machining bit, and one or more movable components known as clamps. These clamps (which may be operated by many different mechanical means) allow workpieces to be easily placed in the machine or removed, and yet stay secure during operation. Many are also adjustable, allowing for workpieces of different sizes to be used for different operations. Fixtures must be designed such that the pressure or motion of the machining operation (usually known as the feed) is directed primarily against the solid component of the fixture. This reduces the likelihood that the fixture will fail, interrupting the operation and potentially causing damage to infrastructure, components, or operators. Fixtures may also be designed for very general or simple uses. These multi-use fixtures tend to be very simple themselves, often relying on the precision and ingenuity of the operator, as well as surfaces and components already present in the workshop, to provide the same benefits of a specially-designed fixture. Examples include workshop vises, adjustable clamps, and improvised devices such as weights and furniture.

The following components are included in the manufacturing of the fixture as per the stated design. Some of the components have been manufactured and others are under manufacturing stage. However, the design has been completed. The details of the manufactured components are mentioned below. The images attached are 3D Cad images of the design.

Centre shaft

The center shaft forms the core of the fixture. The back plate, middle plate, front plate are mounted on the center shaft. The center shaft is manufactured from a circular block of diameter 200mm and 300mm length. A hole of 14mm diameter has been drilled in the center of shaft for the passage of the core of the wire rope. Six equally spaced tapped holes of M10 x 1.5p at 150 Pitch circle diameter are made on the front end for fitting the fixture to the mounting wherever needed. Also six more counter bored holes for the passage of wires are placed on the front end of the center shaft. The fixture is will be held to wire rope formation mounting through the holes on the center shaft. The center shaft shown in the following figure depicts exact 3D view.

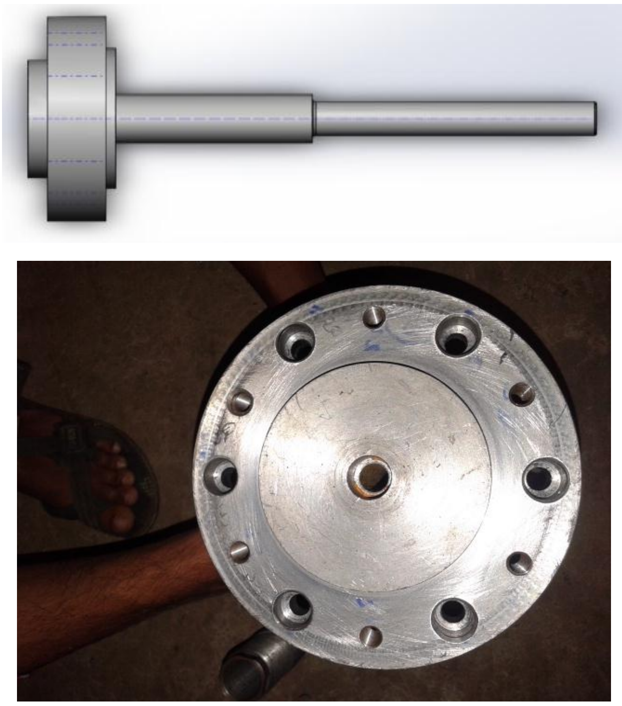


Fig: Centre Shaft.

Back plate

The back plate is the largest manufactured component of the fixture assembly. The wires from the bobbins first enter the holes of the back plate shown as the bigger flange type structure in the figure. The holes are counter bored for the provision of fitting of ferrule in the bigger section of the holes. The holes are 12 in number and are equidistantly spaced. The smaller tapered section shown in the second figure is the front end of the plate. It has 6 tapped holes of M12 x 1.75p x 20 depth. These holes are for the placement of the rollers. The rollers are placed on M12 type of bolts. The back plate is mounted on the centre shaft through the centrally provided hole of the back plate. During assembly the back plate is bolted to the centre shaft.

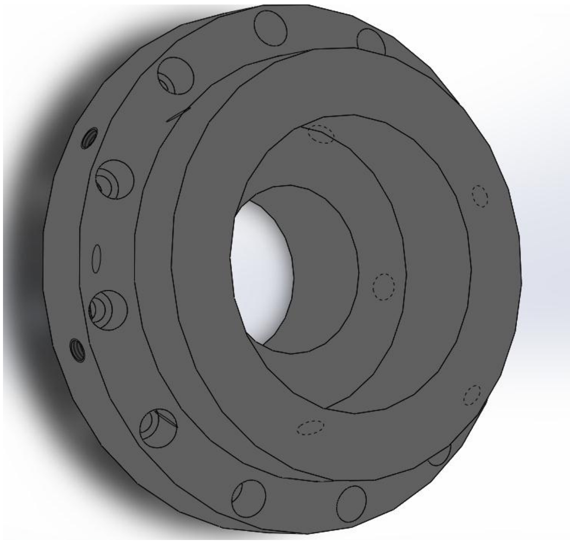


Fig: Back plate (Back end).

Middle plate

The middle plate comes after the back plate. It is placed between the back plate and the front plate. It is mounted on the center shaft after the back plate. It has six holes on the outer periphery for the mounting of rollers. The hollow section inside is threaded to suite the mounting. The roller mounting holes are of same dimensions as they are on the back plate. The middle plate has threads so that it can be adjusted as per requirement.

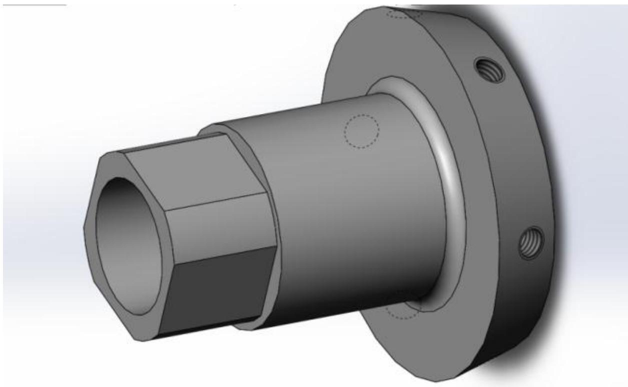


Fig: Middle plate

Front plate

The front plate is comes at the front of the fixture. It is the smallest of the three plates and does not have any projected cross-section. It has a chamfered outer periphery. The holes for mounting the rollers are placed on this. It has 6 tapped holes of M12 x 1.75p x 20 depth. These holes are for the placement of the rollers. The rollers are placed on M12 type of bolts. The hollow part of the front plate is threaded for suiting its mounting on the center shaft. Also it can be adjusted as per require.

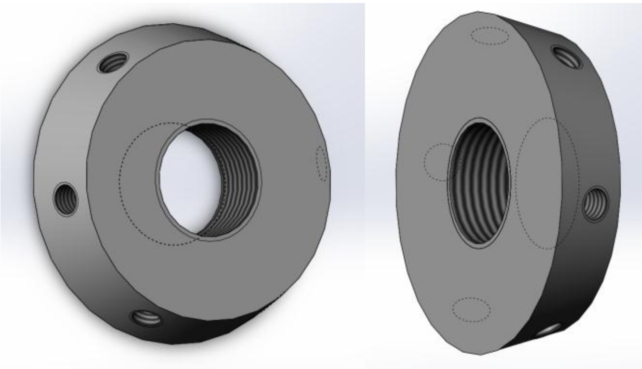


Fig: Front plate.

Guide plate

Guide plates are used as the supporting structure for the Pre-Form wire rope fixture. There are two guide plates used.

The total length of guide plate is 230mm and it has curved from the focal length of 92mm. One end of the plate carries a hole of 11mm Diameter for fixing the plates and on the other end there is a through tap welded to fix the supporting ring. There is a key slot at the center of the guide plates it prevents the rotation of the guide plate and provides extra support to the front plate.

Fig: Guide plate.

Supporting ring

The supporting ring is circular hollow plate is used to support the structure with guide plates. The guide plates are tapped on the supporting ring. There are six tap holes on the supporting ring of 11mm diameter. These holes drilled at two groups of three holes on each half circle and are at equal distance. This is used for safety of rollers and inner plates.

Main purpose of this guide plate and supporting ring is to avoid impact on inner structure during work, as during the actual working sessions the roller must not come in contact with foreign objects. Thus the use of supporting ring is essential.

The supporting ring has outer diameter of 220mm and inner diameter of 170mm, has the thickness of 10mm.

Fig: Supporting Ring.

Threaded shaft

Threaded shaft is mounted on the center shaft. The length of the threaded shaft is 132mm and its outer diameter is 38mm and internal diameter is 30mm.Threaded shaft is used to support two plate front plate and middle plate.

Fig: Threaded shaft.

Ferrule

Ferrule is placed in the hole on the back plate near the periphery. The wire strands are passed through the ferrule. It has smooth curved venture to provide the smooth pass of the strands. There are 12 number of holes on the center shaft for the placement of the ferrules and every hole consists one ferrule. The composition of ferrule is Tungsten Carbide. The ferrule is hardened & tampered with finish hardness 58 to 60 HRC.

Standard table for selection of ferrule (Fig.)

ITEM	Ø d	Ø D	L
1	$\frac{1}{8}$"	$\frac{3}{8}$"	$\frac{3}{8}$"
2	$\frac{3}{16}$"	$\frac{3}{8}$"	$\frac{3}{8}$"
3	$\frac{1}{4}$"	$\frac{7}{16}$"	$\frac{3}{8}$"
4	$\frac{5}{16}$"	$\frac{9}{16}$"	$\frac{7}{16}$"
5	$\frac{7}{16}$"	$\frac{3}{4}$"	$\frac{9}{16}$"
6	$\frac{5}{8}$"	$\frac{7}{8}$"	$\frac{3}{4}$"
7	$\frac{5}{8}$"	1"	1"
8	3mm	8mm	8mm
9	1"	$1\frac{1}{2}$"	1"
10	$1\frac{1}{4}$"	$1\frac{3}{4}$"	1"
11	$1\frac{5}{8}$"	$2\frac{1}{4}$"	$2\frac{3}{4}$"
12	$\frac{11}{16}$"	$1\frac{1}{4}$"	1"
13	$\frac{3}{4}$"	$1\frac{1}{4}$"	$\frac{3}{4}$"
14	1"	$1\frac{1}{4}$"	$\frac{3}{4}$"
15	16mm	22mm	20mm
16	14mm	20mm	18mm
17	$\frac{1}{2}$"	$\frac{7}{8}$"	$\frac{7}{8}$"
18	12mm	18mm	18mm
19	$\frac{3}{8}$"	$\frac{5}{8}$"	$\frac{7}{8}$"

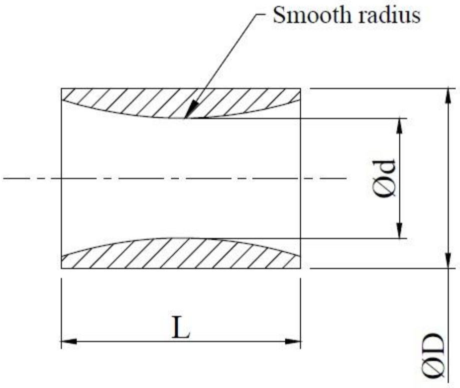


Fig: Ferrule.

Testing

After the assembly of Preform Wire Rope Fixture, the wire-rope manufactured using it and the wire-rope manufactured by conventional wire rope manufacturing process were tested and the results were analyzed.

The tests were performed on both the wires-ropes on the Universal testing machine in a standardized testing laboratory upon conventional wire ropes and wire ropes formed with the use of Pre-form Wire-Rope Fixture prototype.

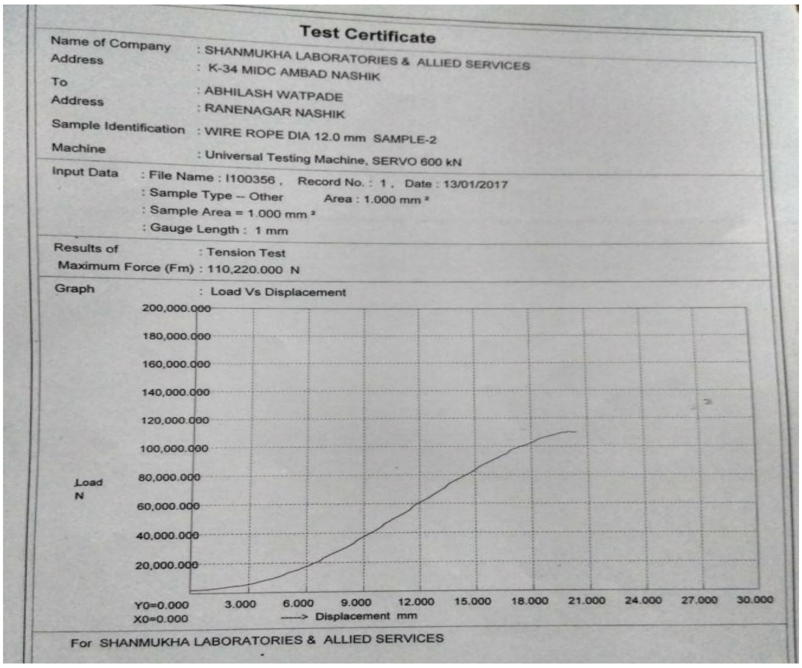
Both the wire samples are tested by Universal Testing Machine to determine breaking load @ Shanmukha Laboratories, Ambad, Nashik

The wire-rope manufactured by conventional wire rope manufacturing process was able to sustain a load of 89 kN after which it broke. The Strand which was unequally stressed was the first to break. The failed strand can be seen in the below picture.

The wire-rope manufactured by using Pre-form Wire-Rope Fixture prototype sustained a load of 110 kN. The breakage was uniform and the stressing was nearly equal in all the strands.

Fig: Wire ropes after testing.

Results for Wire Manufacture without using PFWR Fixture

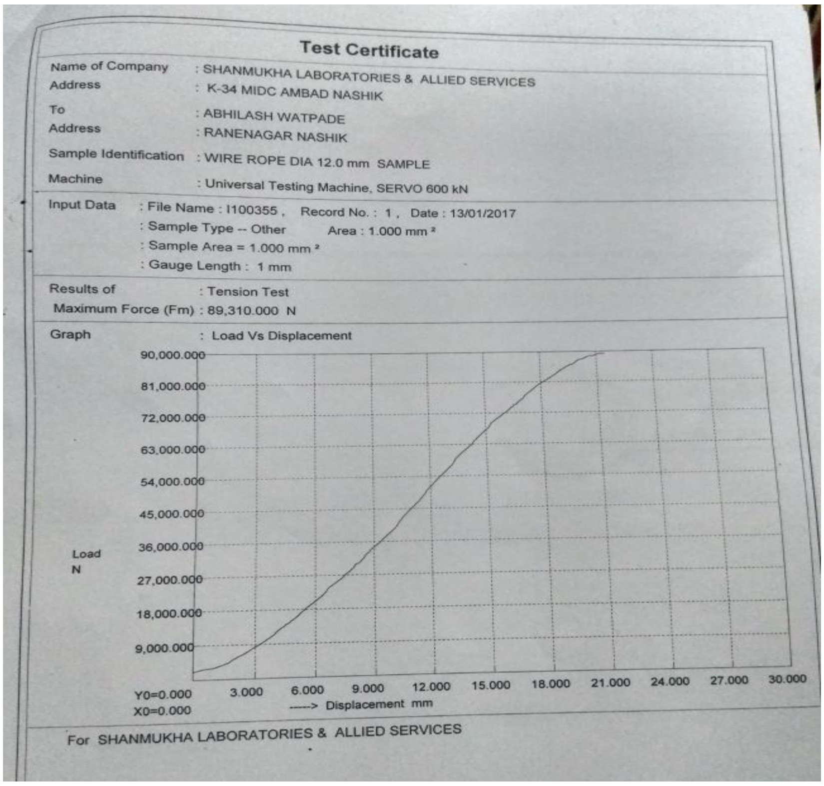


Test Certificate

Name of Company : SHANMUKHA LABORATORIES & ALLIED SERVICES
Address : K-34 MIDC AMBAD NASHIK
To : ABHILASH WATPADE
Address : RANENAGAR NASHIK
Sample Identification : WIRE ROPE DIA 12.0 mm SAMPLE-2
Machine : Universal Testing Machine, SERVO 600 kN
Input Data : File Name : I100356 , Record No. : 1 , Date : 13/01/2017
: Sample Type -- Other Area : 1.000 mm ²
: Sample Area = 1.000 mm ²
: Gauge Length : 1 mm
Results of : Tension Test
Maximum Force (Fm) : 110,220.000 N
Graph : Load Vs Displacement

For SHANMUKHA LABORATORIES & ALLIED SERVICES

Results Obtained from rope Manufactured with using PFWR Fixture


Test Certificate

Name of Company : SHANMUKHA LABORATORIES & ALLIED SERVICES
Address : K-34 MIDC AMBAD NASHIK
To : ABHILASH WATPADE
Address : RANENAGAR NASHIK
Sample Identification : WIRE ROPE DIA 12.0 mm SAMPLE
Machine : Universal Testing Machine, SERVO 600 kN
Input Data : File Name : I100355 , Record No. : 1 , Date : 13/01/2017
: Sample Type -- Other Area : 1.000 mm²
: Sample Area = 1.000 mm²
: Gauge Length : 1 mm
Results of : Tension Test
Maximum Force (Fm) : 89,310.000 N
Graph : Load Vs Displacement

For SHANMUKHA LABORATORIES & ALLIED SERVICES

RESULTS

The Breaking Strength of WIRE ROPE without using PREFORM WIRE ROPE FIXTURE is: 89.31 KN.

The Breaking Strength of WIRE ROPE with using PREFORM WIRE ROPE FIXTURE is: 110.220 KN.

From above results we can conclude that the PREFORM WIRE ROPE FIXTURE increases tensile strength of wire-ropes by upto 24%.

COST ESTIMATION

Total cost = Raw Material cost + Processing cost + Cost of Std. parts + Cost of testing

1) Raw Material cost

1. Mild steel blocks = Rs.15,000
2. Coolants = Rs.500

Total Raw material cost = Rs.15,000 + Rs.500 = Rs.15,500

2) Processing cost = Rs.20,000

3) Cost of Standardized parts

1. Cost Ferrule = Rs.65 x 24 Nos. = Rs.1,560
2. Cost of rollers = Rs.95 x 18 Nos. = Rs.1,710
3. Cost of roller pins = Rs.75 x 18 Nos. = Rs.1,350

Total parts costs = Rs.1,560 + Rs.1,710 + Rs.1,350 = Rs.4,620

4) Cost of Testing = Rs.1,000

Therefore,

Total cost = Rs.15,500 + Rs.20,000 + Rs.4,620 + Rs.1,000

= Rs.41,120

The above mentioned cost does not include the cost of transportation and other miscellaneous costs. Therefore, considering an overhead of 10% the final cost becomes.

Final cost = Rs.41, 120 + (0.1 x 41120) = Rs.45, 232

Thus the total cost for the prototype amount to Forty-five thousand two hundred and thirty two rupees.

CONCLUSION

The parts of the Preform Wire Rope Fixture were separately manufactured by conversion of the raw material blocks into the final part by employing various manufacturing processes like milling, drilling, turning, facing cutting grooving etc. The parts like ferrule and rollers and pins which are available in standardized specifications and require special processes for manufacturing were successfully procured from the market suppliers. The prototype of Preform Wire Rope Fixture was then successfully assembled and put to various tests. The prototype was then sent to the company for the manufacturing of the wire-rope. The manufactured samples of the wire-rope were then procured from the manufacturing facility for the purpose of the testing and to check the effectiveness of the fixture. These samples along with the samples earlier manufactured without using the fixture were sent to a standardized laboratory for the purpose of the testing to check the tensile strength. The sample of wire-rope manufactured without using the fixture sustained a breaking load of 89 kN and the sample of wire-rope manufactured using the fixture sustained a breaking load of 110 kN. Therefore it can be concluded that the fixture is quite effective during the manufacturing process and the increase in the strength was by 24%. The total cost for the prototype amount to Forty-five thousand two hundred and thirty two rupees.

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