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Modification of 2D Conventional Weaving Machine for the Fabrication of High Performance Woven Preforms: Part-I: Design and Manufacturing of Warp Creel

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ABSTRACT

The Woven preforms are generally manufactured by weaving technique using either complex 3D weaving machines or especially designed patent machines. The advantage of conventional technique lies in the flexibility of yardage production and composite may be developed by lamination or directly using 3D multilayer structure. Due to the stiffer nature of high-performance fibers, the conventional weaving technology causes damage of fibers in general and strength and modulus in particular. The warp creel is one of the main elements of weaving machine which is responsible for such fiber damage due to inflexible unwinding of fiber spool caused by friction. Therefore, in this research, a warp creel with novel features has been designed and manufactured to replace the conventional warp beam for smooth processing of high performance fibers. For this purpose, different parts of the proposed warp creel were designed and manufactured, including creel frame and adjustable spindles. These parts were manufactured with different specifications and order to carry out the smooth processing of high-performance tow. All these parts were manufactured with MS steel. The developed warp creel was used for the production of high-performance fiber preforms. In this study, three different high-performance fibers (Carbon, Kevlar and Glass) were used to fabricate plain woven preforms.The main objective of this research is the preclusion of the fibers/filaments from deterioration from weaving mechanism. The results showed the minimum number of filaments of carbon tow being damaged. The use of MS steel material and highly polished parts resulted in least amount of frictional contacts which in turn improved the apparent quality of the formed preforms.

Key Words: Warp Creel, 2D Conventional Weaving Machine, High-Performance Fibers, Woven Preforms.

1. INTRODUCTION

The textile preforms are the general class of engineering materials [1] manufactured to confirm desired shape and specific mechanical and structural characteristics. Many of textile preform manufacturing processes including weaving, braiding and knitting developed in ancient times are still used in remote areas of the world today. From these methods, conventional weaving is one of the most important preform manufacturing processes [2] but it has drawback of deterioration of mechanical properties of high-

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performance fibers such as Carbon, Glass and Aramid fibers. However, with the advent of the industrial age, rapid developments in machinery and textile manufacturing techniques have advanced the science of textiles [3]. Over the last decades, several textile technologies have been developed to manufacture textile preforms for fields such as aerospace, automotive, transport, sports, wind energy and off-shore. The aim was to improve the mechanical performance [4]. Due to design versatility woven preforms are playing important roles in meeting the high-performance demands for technical applications because the weaving technology is able to use a variety of raw materials and to convert them into products with various geometrical forms [5]. In conventional looms warp yarns are supplied from warp beam that contains thousands of individual warp yarns [6]. Fig.1 shows conventional warp beam, is an iron rod when empty weighs up to 30 kg. If it is loaded weighs up to 300 kg [7]; therefore, beams with this huge weight are not suitable for high-performance fiber weaving. Also for preform fabrication lesser number of warp yarns is required; thus, warp yarns or tow are supplied directly from creel which necessitates extra flexibility in unwinding and guiding fiber tow on its way to main weaving zone. The diameter of yarn is in microns; whereas, the width of high-performance fiber tow is 4-16 mm. Moreover, the high-performance fibers are very delicate with zero twist which cannot be processed in conventional weaving machine because of friction with different loom parts and excessive tension. It is also known that the fibers get abraded against each other and with the loom machinery during weaving, and the resulting abrasion damage causes a reduction in yarn strength of between 30 and 50% depending on the type of yarn [8]. This research is based on designing and development of warp creel for manufacturing of textile preforms from high-performance fibers (Carbon, Kevlar, Glass etc) which has overcome the problem of spool unwinding and excessive friction in creel parts.

1.1 MATERIAL

For this research 2D conventional weaving machine was selected. The warp creel is designed and manufactured instead of warp beam for high performance fibers. All the components of creel portion are manufactured from MS steel, Nylon shaft (polymer), polished rod (MS steel shaft), and stainless steel wires (2mm). The machine used for the manufacturing of all warp creel parts are cut-off machine DEWALT (D28720) German, Lathe machine, electronic arc welding machine.

2. DESIGN OF DIFFERENT PARTS OF WARP CREEL

The warp creel is used to unwind and feed the carbon tow to 2D conventional weaving machine to manufacture

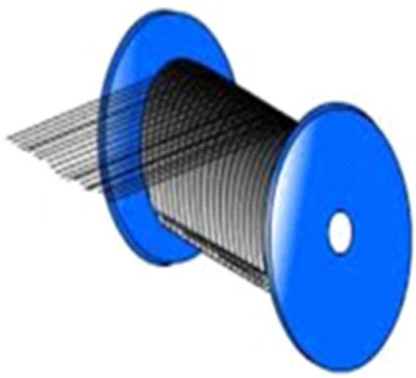


FIG.1 CONVENTIONAL WARP BEAM

woven preforms. The straight type warp creel with the capacity of 21 spindles, for holding high performance fiber tow spools. Seven polished rods are used and three spindle in each rod. Fig.2, 3 and 4 show the 2D, 3D and dimensions of warp creep. The design of warp creel consists of two major parts, creel frame and adjustable spindles.

2.1 Creel Frame

The creel frame was manufactured from MS steel. It consists of different parts. These parts were designed and manufactured from MS steel. The frame of creel was manufactured from MS steel square pipe of 38mm diameter. The length and width of creel were 1829mm and 1524mm respectively. Seven polished rods were fixed to hold spindles, each rod contains three spindles. The diameter of each rod was kept 19.05mm. Fig.5 and 6 show 2D and 3D views of polished rods. The round clips were manufactured to hold rods. The length of clips was 140mm and thickness was 4mm. The internal diameter of clips was 19.05mm. Fig.7 and 8 show 2D and 3D views of warp creel clip. The four wheels of 63.5mm in diameter with brakes were fitted at the bottom of the creel for adjusting the creel. Fig.9 and 10 depicts 2D and 3D drawing of wheels. Table 1 shows the specifications below of all these components prepared for this study.

FIG.3 THREE-DIMENSIONAL VIEW OF WARP CREEL

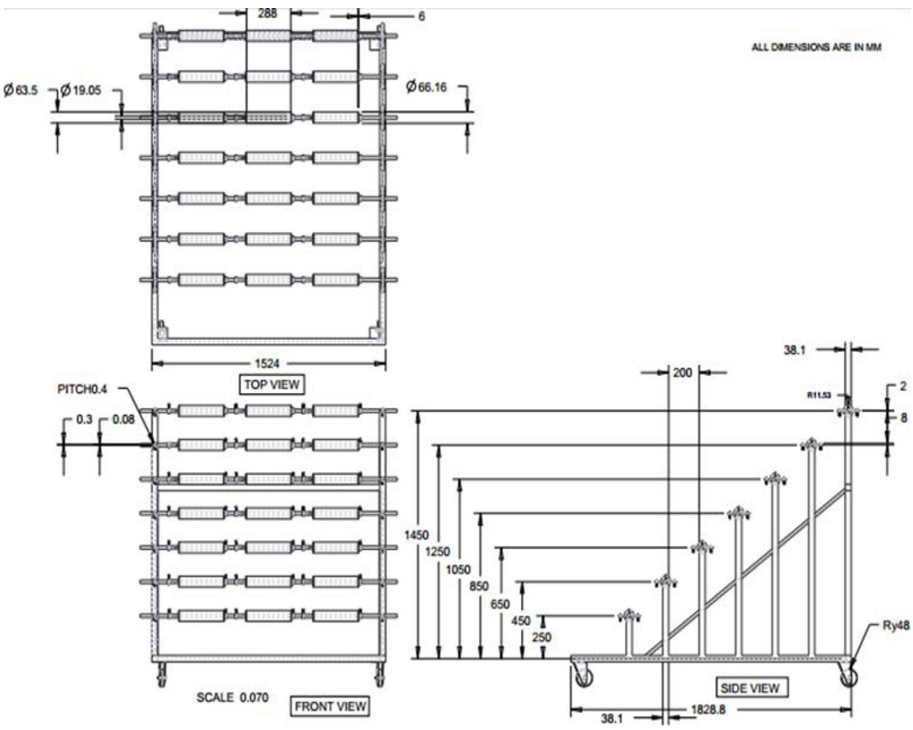


FIG.2 TWO-DIMENSIONAL VIEWS OF WARP CREEL

2.2 Adjustable Spindle

The adjustable spindles were made from MS steel polished rods to hold the cheese of carbon tow packages for manufacturing of textile composite preforms. Fig.11 and 12 show 2D and 3D views of adjustable spindle. Its flexibility lies in its design to hold different package diameters. The 63.5 mm diameter nylon plates were used to hold and provide ease in the unwinding of carbon packages. The collar of nylon plate was 6mm and the internal diameter was 78mm with external diameter of 78mm. Fig.13 and 14 show 2D and 3D views of round nylon plates. The hollow center of nylon plate was made with round bush attachment to move smoothly on the polished rod. The stopper bushes were used to stop the spindle to avoid excessive unwanted and reverse movement of spindle. Fig.15 and 16 show 2D and 3D views and dimensions of stopper. The round stopper bushes were made with nut and bolt. The nut and bolt are fixed on the top of the stopper bush to fix on the polished rod. The stopper bush is also adjustable. It depends upon the sizes of the spindle package. The stopper bush has internal diameter of 19mm and external diameter of 32mm; whereas, it has thickness of 7mm.The springs were added to adjust the tension of the spindles. Figs. 17-19 show 2D and 3D drawings of spring. The diameter of spring was 19.05mm and the thickness of wire of springs was 2mm. Table 2 shows the specifications.

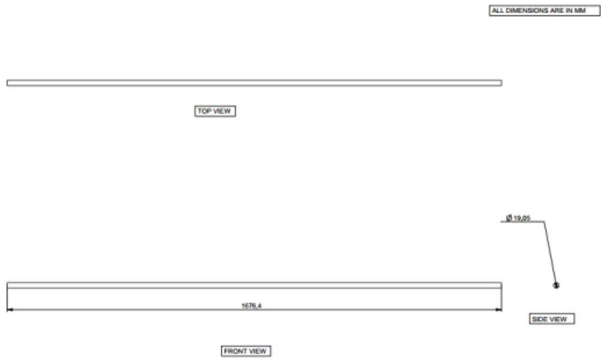


FIG.5 2D VIEW OF POLISHED ROD

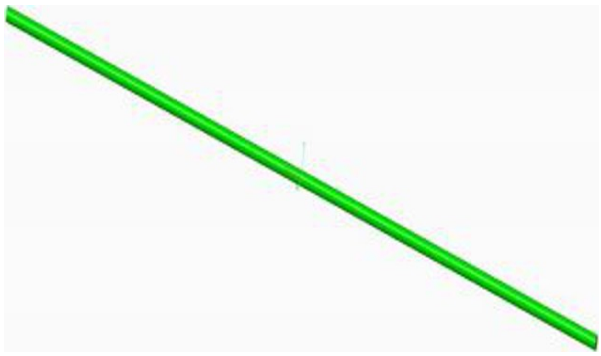
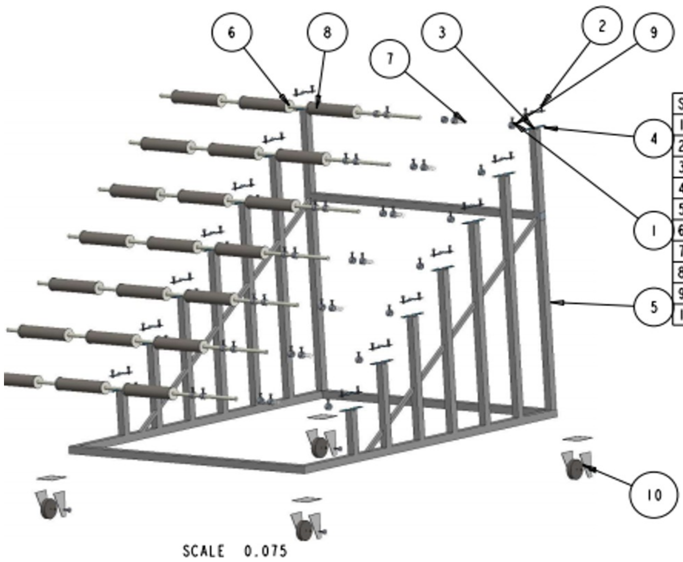


FIG.6 3D VIEW OF POLISHED ROD



S. No	Name	Type	Quantity
1	BOLT7MM	PART	39
2	BOLT8MM	PART	28
3	CLIP	PART	28
4	NUT8MM	PART	28
5	PRT0002	PART	1
6	SLOT	PART	7
7	SPRING	PART	21
8	SPUNDLE	PART	21
9	STOPPERI	PART	42
10	WHEEL	ASSEMBLY	4

FIG.4 THREE DIMENSIONAL VIEW AND DIMENSIONS OF WARP CREEL

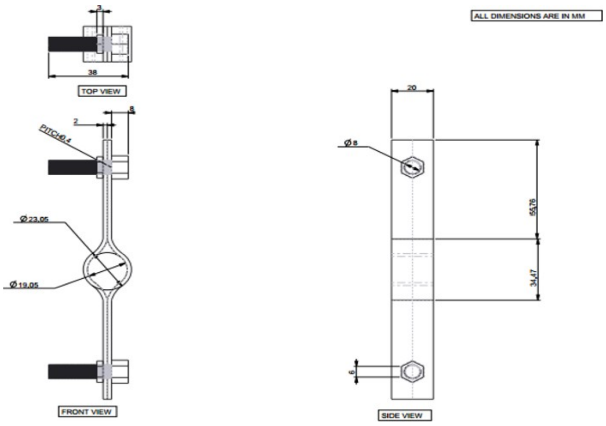


FIG.7 3D VIEW CLIP

FIG.8 2D VIEWS OF WHEEL

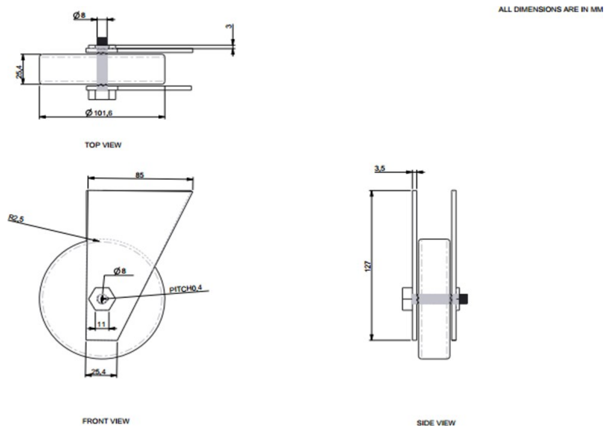


FIG.9 3D VIEW WHEEL

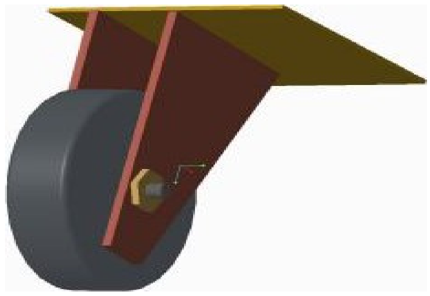


FIG.10 2D VIEWS OF ADJUSTABLE SPINDLE

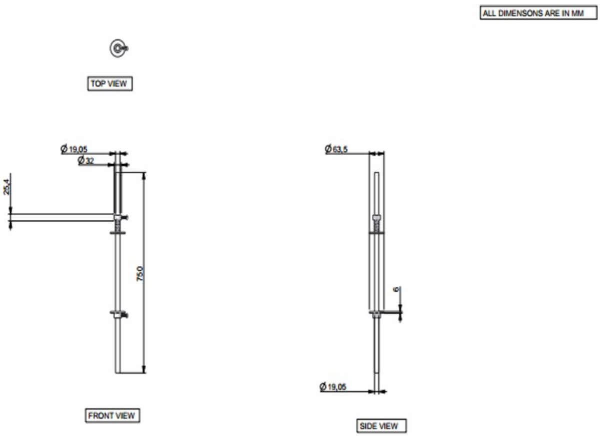


FIG.11 3D VIEW OF ADJUSTABLE SPINDLE

FIG.12. 3D VIEW OF ADJUSTABLE SPINDLE

TABLE 1 SPECIFICATION OF CREEL FRAME PARTS

Parts	Length (mm)	Width (mm)	Thickness (mm)	Internal Diameter (mm)	External Diameter (mm)
Square pipe	1828.8	1524	2	38	40.2
Polished rods	19.05	1524	2	19.05	19.02
Clips	14	24	4	19.05	19.05

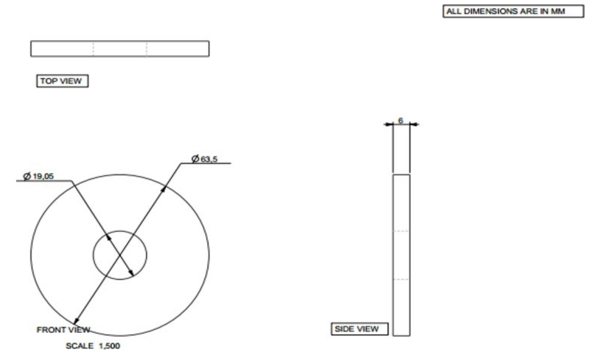


FIG.13. 2D VIEWS OF ROUND NYLON PLATE

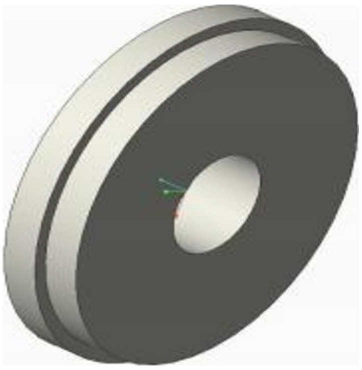


FIG.14 2D VIEWS OF ROUND NYLON PLATE

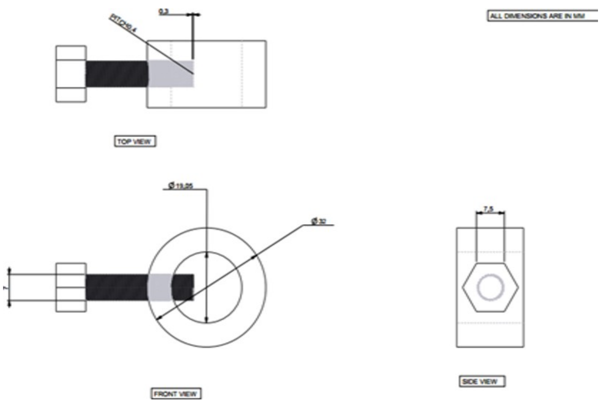


FIG.15 3D VIEW OF ROUND NYLON PLATE

FIG.16 2D VIEWS OF STOPPER

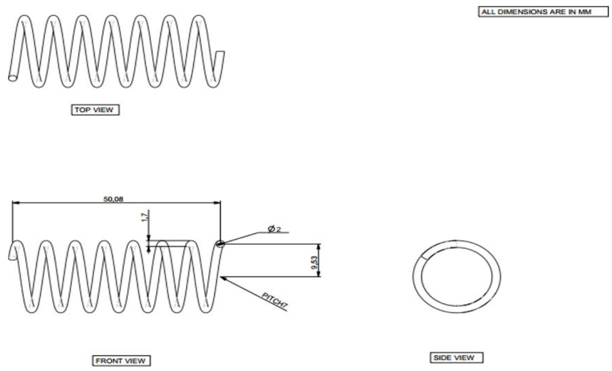


FIG.17 3D VIEW OF STOPPER

FIG.18 2D VIEWS OF SPRING

TABLE 2 SPECIFICATION OF ADJUSTABLE SPINDLE PARTS

Parts	Length (mm)	Width (mm)	Thickness (mm)	Internal Diameter (mm)	External Diameter (mm)
Round nylon plate	28	18	82	78	78
Round nylon plate bush	24	18	5	19	24
Stopper bush	10	18	7	19	32
Spring	24	55	2	19.05	23

After the completion of designing, manufacturing and assembling phases of different parts of warp creel, its performance was evaluated during production of 2D preforms using 2D conventional weaving machine. The performance of newly designed creel was very good when tested for three different high-performance fibers (Carbon, Kevlar and Glass) which were used to manufacture plain woven preforms. Figures. 19-21 show plain weave design (1/1) woven preforms. Table 3 shows different parameters of woven preforms construction.

3. DETAILS OF PREFORMS CONSTRUCTION

For this study warp tows of carbon 12k denier, Kevlar 1130dtex and glass 4200 tex were selected. The preform structure was plain weave of (1/1).

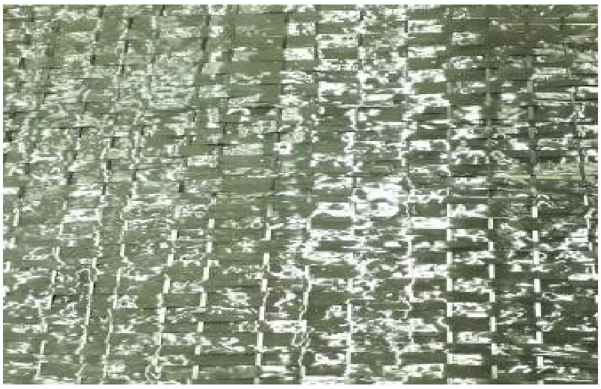


FIG.19 3D VIEW OF SPRING

$$\text{Quality of Carbon preform} = \frac{warp\ count \times weft\ count}{{ends}/{inch} \times {picks}/{inch}} \times width\ of\ fabric$$

$$= 12000 \times 12000/2 \times 5 \times 21$$

$$= 144{,}000{,}000/10 \times 21$$

$$= 14{,}400{,}000 \times 21$$

$$= 302{,}400{,}000$$

FIGURE 20 CARBON PREFORM PLAIN WEAVE (1/1)

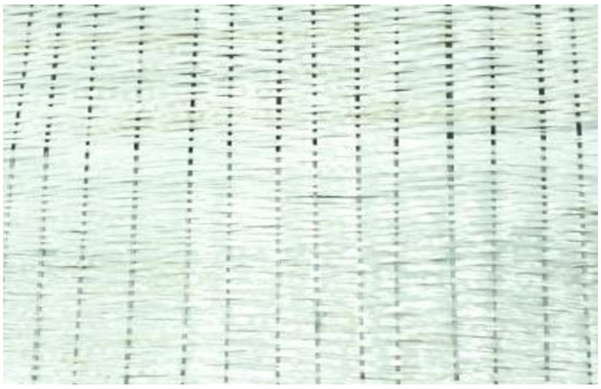


FIGURE 21 KEVLAR PREFORM PLAIN WEAVE (1/1)

TABLE.3 WOVEN PREFORM PARAMETERS

S. No.	High Performance fibers	Carbon preform	Kevlar preform	Glass preform
1.	Weave Design	Plain Weave (1/1)	Plain weave (1/1)	Plain weave(1/1)
2.	Warp Tow	Carbon	Carbon	Carbon
3.	Weft Tow	Carbon	Kevlar	Glass
4.	Warp count	12000	12000	12000
5.	Weft count	12000	1130	4200
6.	Ends/inch	2	2	2
7.	Picks/inch	5	8	11
8.	Fabric width	21	21	21

$$\text{Quality of Kevlar preform} = \frac{warp\ count \times weft\ count}{ends/_{inch} \times picks/_{inch}} \times width\ of\ fabric$$

$$= 12000 \times 1130 / 2 \times 5 \times 21$$

$$= 13,560,000 / 10 \times 21$$

$$= 1,356,000 \times 21$$

$$= 28,476,000$$

$$\text{Quality of Glass preform} = \frac{warp\ count \times weft\ count}{ends/_{inch} \times picks/_{inch}} \times width\ of\ fabric$$

$$= 12000 \times 4200 / 2 \times 11 \times 21$$

$$= 50,400,000 / 22 \times 21$$

$$= 2,290,909.09 \times 21$$

$$= 48,109,090.90$$

Total no. of ends: 21

4. CONCLUSION

An innovative work of manufacturing warp creel with some unique and specific attributes has been successfully performed. While replacing the conventional complex warp beam, the newly designed warp creel showed excellent features. The main objective of this research was the preclusion of the fibers/filaments from deterioration from weaving mechanism. The results showed the minimum number of filaments of carbon tow being damaged. The use of MS steel material and highly polished parts resulted in least amount of frictional contacts which in turn improved the apparent quality of the formed preforms.

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