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DESIGN OF A LIGHT WEIGHT STRETCHER WITH A FOLDING MECHANISM

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Abstract
In the coastal area of the Niger Delta of Nigeria, wheeled vehicles are hindered because of the rough terrain. This has increased the number of deaths especially in battle fields and in an emergency situation. Therefore, the design of a lightweight stretcher with folding mechanism became necessary in such regions of the Niger Delta of Nigeria. This design presents some problems ranging from material selection, mechanism selection, and design parameters. The equations of bending and deflection were used within a reasonable factor of safety. Tarpaulin confutes, which can carry a weight as much as 100kg, was used as the plate to ensure lightness of the stretcher. In addition, plain carbon steel was used as the stretcher beam.

NOMENCLATURE

wl-Point load
M-Bending moment
Mx-Moment at some point$x$
l-Length
W-Distributed load per unit length
σ_b-Bending stress
I-Moment of inertia
Gs–Distance from the top cross-section to the neutral axis
E-Young modulus
δ-Deflection of beam
σ_{max}-Maximum stress
n-Factor of safety
Sy-Yield stress
Ssy-Shearing yield stress
UNS-Unified Number System
L-Spring rate
d-Wire diameter
D-Spring mean diameter

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G-Modulus of rigidity
N-Number of spring coils
C-Spring index
$\boldsymbol{Fmax}$-Maximum force
$\boldsymbol{F_{all}}$-Allowable force

1. INTRODUCTION

A stretcher is a medical device used to carry casualties or an incapacitated person from one place to another. It is a simple type of lifter called by that name. A stretcher is usually carried by at least two persons, one at the head and the other at the feet. The patient is placed on the stretcher and then carried to the hospital for treatment, this usually occurs when the person is unable to work. Stretchers have been used since time immemorial, especially in battlefields and in an emergency situation, where wheeled vehicles are hindered by rough terrain. This has increased the number of deaths, especially in battlefields. Therefore, the design of a lightweight stretcher with folding mechanism, which can be carried with ease into such rough terrains became necessary. Stretchers in their support form, generally consist of a canvas sling with long edges sewn to them to form pockets through with wooden poles. This has been in use ever since, especially by the military, right through the middle of the 20^{th} century. .

In developed nations, there has been great advancement in material science, lightweight stretchers weighing as little as 2kg, which can carry load up to 180kg, have been developed. Haynes (2002), has entirely different approach. He based his work on the theory of elasticity and plasticity. However, he opined that the simple theory of bending and deflection of beam equations would give the same results when analysing the design of the stretcher beam (Haynes, 2002). Cavalcanti (2010) investigated and built a new stretcher for standard ambulances. His goal was to reduce vibrations experienced by patients, reduce the amount of weight, and simplify user operation while maintaining a high level of safety, comfort, and patient-centred care.

However, Patenza (2002) based his design calculations on fracture mechanics and, as well as theory of elasticity and plasticity. He obtained a slightly different result when compared with that of Haynes (2002). The beam design uses the theory of bending and deflection of beams which give the same results (Haynes, 2002; Rashid, et al., 2010).

Vines, *et; al.*, (2017) designed a multipurpose stretcher by combining the architectures of stretchers and wheel chairs. The design tended to solve the problem of shifting injured or fractured patients from stretchers to wheelchairs. The model consists of three rectangular couches that are joined together. These joints are not permanent, they are adjustable to any angle and can be assembled or dismantled based on the health condition of the patients.

Cole (2018) examined the relationship between Emergency Medical Services (EMS) employment turnover, retention, and recruitment and stretcher systems. The study used a causal comparative design, survey solicitation of data, and multivariate analysis of covariance as the statistical methodology. The researcher concluded that the stretcher type does not influence recruitment, retention, or turnover. This study improves the understanding of workforce outcomes as influenced by the type of stretcher systems used in EMS.

The above reviewed work armed the researcher in the design of a light weight stretcher with a folding mechanism to solve the problem faced in the swampy region of the Niger Delta of Nigeria.

2. MATERIALS AND METHODS

In this work, one of the major considerations is the design of the weight of the stretcher since the persons carrying the stretcher will have to carry the weight of the stretcher and, as well as the weight of the person on it. Therefore, the primary aim of this research is to design a stretcher as light as possible and carry the weight of the affected person without failure. In line with the local content objective, we use locally available materials as follows:

The tarpaulin nylon used for the construction of the stretcher plate must not fail under a critical load by yielding.
The horizontal beam will not yield under a critical load of 1000 N.
The spring used in the folding mechanism must be investigated to ensure that it will not fail due to fatigue.

Design Considerations

A x w *per unit length* **B**

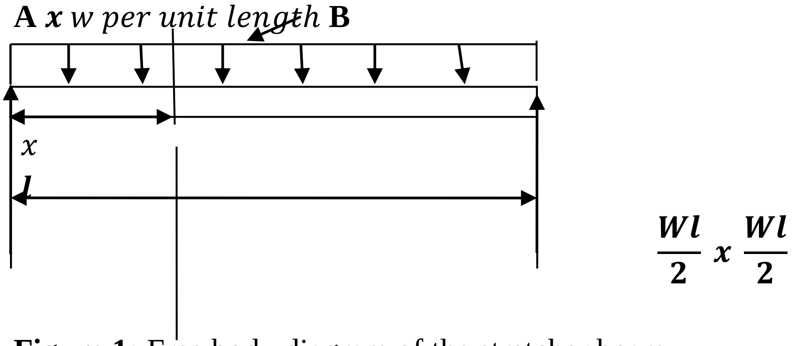

Figure 1: Free body diagram of the stretcher beam.

Figure 1 shows a simple supported stretcher beam AB of span and carrying a uniformly distributed load, w per unit run over the whole span with each vertical reaction equals to $\frac{wl}{2}$ .Considering a section xx at a distance x from the end A of the stretcher beam, where,

$M_x = \frac{wlx}{2} - \frac{wx^2}{2}$ ------------------------ (1)

w = rate of distribution per unit length, l= length of the stretcher beam, and M_x= Moment about the section xx.
As the load is symmetrical, the maximum deflection will occur at the mid span of the stretcher beam, hence $\frac{dM_x}{dx}$ = 0. By differentiating equation (1) with respect to x, and substituting $\frac{l}{2}$ for x into equation (1) we obtain,

$M_x = \frac{wl}{2} . \frac{l}{2} - \frac{w}{2}\left(\frac{l}{2}\right)^2$ -------------------- (2)

$M_x = \frac{wl^2}{8}$ ----------------------------- (3)

Following the theory of simple bending, we obtain,

$\frac{\sigma_b}{Y} = \frac{M_{max}}{I}$ ------------------------(4)

Where, M_{max}= Maximum bending moment
Y=distance from the top cross- section to the neutral axis, i=moment of inertia, σ_b= bending stress
For a rectangle cross- section,

$Y = \frac{d}{2}$ ----------------------------------(5)

Substituting equations (3) and (5) into equation (4), we obtain,

$\sigma_b = \frac{wl^2 d}{16I}$ -------------------------------- (6)

Hence, the maximum bending stress is

$(\sigma_b)max = \frac{wl^2 d}{16I}$ -------------------- (7)

The maximum deflection (δ_{max}) of a simple supported stretcher beam with a uniformly distributed load, will occur at the center of the beam, and so we introduce an imaginary force F acting downward at this point. The end reactions are,

$R_1 = R_2 = \frac{wl}{2} + \frac{F}{2}$ --------------------- (8)

Hence, by solving equation (1) using the double integration method, we obtain,

$\delta_{max} = \frac{5wl^4}{384EI}$ ----------------- (9)

The moment of inertia, i is given as,

$i = bd^3 - (b - 2t)(d - 2t)^3$ ---------------(10)

Where b = width of the beam cross- section,

t = thickness of cross- section.

From equation (10) b can be deduced as,

b = $\frac{12I + 2t\,(d-2t)^3}{d^3 - (d-2t)^3}$ ------------------ (11)

Dividing equations (7) and (9), we obtain,

d = $\frac{80l^2(\sigma_b)max}{384E\delta_{max}}$ --------------------- (12)

With a safety factor of n

$(\sigma_b)max = \frac{s_y}{n}$ ---------------------- (13)

Where, s_y = yield stress of the beam, hence,

d = $\frac{80s_y l^2}{384En\delta_{max}}$ --------------------- (14)

According to WHO (2004), the average weight of a human being is 70kg while its average height and cross-section is $1.63m \times 0.58m$. The load in this design is taken to be 100kg (that of a fairly plumpy or fat person), while the height is taken as 2.0m, This includes allowances for the handles. A plain cheap carbon steel with unified numbering system (UNS) designation G10400 is used as the stretcher beam. The beam is coated with a thin layer of chromium to prevent corrosion.

Assuming a maximum deflection of 10mm, and a safety factor of 2, and putting the corresponding values $s_y = 275.6\ Mpa,\ l = 2.0m$ and E = 206.7 into equation (14), then we obtain, d = 0.056m or 5.6cm.

$i = \frac{5wl^4}{384E\delta_{max}}$

The load considered in this design is 100kg, hence,

w = mg

w = 245.25N

Therefore,

$i = 2.472\times 10^{-8} m^4$

Assuming a thickness of 2mm, and putting the values of i, d, and t into equation (11), we obtain,

b = 2.5cm or approximately 3.0m.

A hollow beam with a cross-section 3.0m× 5.6cm and a thickness of 0.2 cm will be selected. This selected beam is readily available in the market (Waghmare*et al.*, 2015)

Design consideration of Tar Paulin Material (Corfute)

Due to the design requirement of the stretcher, a material confute, which is made using nylon 6.6 yarn (condura R by M/S Dupont), has been developed. Confute is a tarpaulin material made from reinforced polyethylene nylon. This material has excellent material properties and; also offers resistance to bacterial mold growth, fungal water, and corrosion. It is 60% lighter than another canvas material being used. It has weather capabilities, takes drying times, offers ruggedness, strength endurance, excellent abrasion resistance, good tear, puncture resistance and extreme fade resistance. Due to the stretcher dimensions, confute tarpaulin of 0.067 m × 0.004 m will be required to form the stretcher dimension. The allowance of 0.007m is necessary for the embodiment (wrapping) of the confute tarpaulin around the stretcher beam.

Design Consideration of the Spring within the Folding Mechanism

For design economy, an oil- tempered wire (0.60 – 0.70mm unit of measurement), which is a general-purpose spring steel, is used as the spring material. The universal numbering system (UNS) designation for this spring is G10650.

The spring index is defined as,

$C = \frac{D}{d}$ -------------------------------- (15)

Where D is the mean spring diameter, C is the spring index, d is the wire diameter.

Assuming a wire diameter of 3mm and a spring index of 8 then,

D= 0.024m

The strength under tension is given as,

$S_{ut}\, {}^{A}/_{d^m}$ ----------------------- (16)

Where A = strength intercept of log plot of tension strength, m = slope of the line of log PH, and S_{ut} = ultimate tensile strength. In Shigley (2003), the value of A is 1880Mpa and m is 0.186 for oil – tempered wire.

Putting the values of A, m and d into equation (16), the yield is,

$S_{ut} = {}^{A}/_{d^m} = {}^{1880}/_{3^{0.186}}$

S_{ut}= 1,532.5Mpa

However, yield strength S_y = 0.75S_{ut}

S_y =1,149.4Mpa

The torsional yield strength is given by,

S_{sy} = 0.577S_y= 0.577×1149.4Mpa

S_{sy}= 663.2×10^6pa

The applied force that will cause the spring to yield is given as follows,

$F_{max}=\frac{\pi d^3 \tau}{8K_s D}$ --------------------------- (17)

Since $\tau = S_{sy}$,

$F_{max} = \frac{\pi d^3 S_{sy}}{8K_s D}$ -------------------------------- (18)

But $K_s = 1 + \frac{1}{2c}$,

K_s= 1.0625

$F_{max}= \frac{\pi \times (0.003)^3 \times 663.2 \times 10^6}{8 \times 1.0625 \times 0.024}$= 275.76N

F_{max}= 275.76N

$F_{all} = \frac{F_{max}}{2} = \frac{275.76\text{N}}{2}$

F_{all} = 137.88N

3. RESULTS DISCUSSIONS

These results are acceptable because the maximum allowable force (F_{all}) the hand can comfortably exercise is 220N (Hillborn,2002). When the stretcher is folded, the spring within the hinge is completely compressed to its height. The solid length of the spring is assumed to be 5cm. The stretcher length of the spring is assumed to be 7cm. Hence, the spring constant can be calculated thus;

$F_{all} = K\Delta L$ -------------------------------------- (19)

$K = \frac{F_{all}}{\Delta L}$ -- (20)

Solid length of the spring 5cm =50mm. Stretched length of the spring 7cm =70mm.

$K = \frac{F_{all}}{\Delta L} = \frac{137.88N}{(70-50)mm}$

K = 6.89N/mm

The number of coils N required for the spring is given by the expression,

$$N = \frac{d^4 G}{8D^3 K} \text{ ------------------------------ (21)}$$

Where $G$is the modulus of rigidity for the spring made of oil–tempered wire, G =79.3Gpa. Therefore,

$$N = \frac{3^4 \times 79.3 \times 10^9}{8 \times 24^3 \times 6.89} = \frac{8429761.203}{10^6}$$

N= 8.4 coils

An oil-tempered spring wire with a diameter of 3mm, 8 coils and spring constant (stiffness constant) of 6.89 N/mm is used as the spring for the folding mechanism (hinge).

4. CONCLUSION

In this work, a stretcher made up of plain carbon steel beams and confute tarpaulin was constructed. The weight of the stretcher is about 2kg and it can support a load of 100kg with a reasonable safety factor of 2. This stretcher with folding mechanism can be carried easily in the coastal areas of the Niger Delta of Nigeria where wheeled vehicles are hindered as a result of rough terrain.

5. RECOMMENDATIONS

- A hollow stretcher beam of 2m long, 5.6cm x3.4cm cross-section with a thickness of 2mm is required for construction.
- UNS G10400 is a plain carbon steel and should be plated with a layer of chromium to prevent corrosion.
- The spring in the folding mechanism (hinge) should have hooks at its ends and should have hooks at its ends and eight coils, 3mm in diameter.
- The spring material used should be an oil – tempered wire instead of music wire, which is more expensive.
- The folding mechanisms should be bolted to the stretcher beam and not welded for convenience.
- The confute tarpaulin should be properly embedded (wrapped) round the stretcher beam and the material in every taut.
- Confute tarpaulin has various thicknesses, but one with a thickness of 5mm is preferable.

REFERENCES

Haynes, C.A. (2004); Stretcher Design with lightweight but sturdy Materials,

Available website; www.efunda.com

Hillborn, E.H. (2002). Handbook of Engineering Psychology, pp141.

Patenza, G.Z. (2002). Essential Stretcher Design Mechanics pp.160-191.

Rajput, R.K. (2006). Strength of Materials, 6thEdition, pp. 263.

Shigley, E. (2003). Mechanical Engineering Design, 1st Matrix Edition.

WHO (2004). Human Physiological Statistics pp.307.

______________________________________Cavalcanti, P. M. (2010). Building an Engineered Complex Stretcher. Degree of Bachelor of Science in Mechanical Engineering,

Worcester Polytechnic Institute.

Vignesh, V., Prakash, R., Stephen, M. S., Kumar, S. A. (2017). Design and Development of Two in One Foldable Stretcher cum Wheel Chair. *International Research Journal of Engineering and Technology*, 4(6): 2739- 2745.

Waghmare, S. N., Sawant, N., Dhumal, S., Kedar, N., Patil, P., Dambe, P. R. (2015).Design and Analysis of Compact Stretcher with Rubber Shock Absorbers. *International Journal of Engineering Research, Science and Technology*, 4(2): 128-234.

Cole, G. M. (2018). The Influence of Manual and Hydraulic Stretchers on Recruitment, Retention, and Turnover in the Emergency Medical Services Workforce. A PhD Dissertation submitted to the Graduate School, The College of Science and Technology, The University of Southern Mississippi, USA.

Rashid, A. K., Safar, A. Razack, S. S., Vishnu, K.V., Vishnu, C. R. (2010). Design and Fabrication of Pneumatically Powered Wheel Chair-Stretcher Device.*InternationalJournal of Innovative Research in Science, Engineering and Technology*, 4(1):10278- 10282.