Fatigue Analysis of Slantbed sewing machine needle and flatbed sewing machine needle

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ABSTRACT

In an even more globalized era, the Garment industry is radically changing as consumers are demanding and hoping even more personalized products and in very squat extent. One of the possible avenues, identified, offering the industrial sector possibility to shorten the span of operation. Industrial manufacturing of garment is generally assessed on basis of seam quality, that is directly proportional to needle and components of sewing, A process which is akin to many trades but is very less understood. Contact between needle and material to be sewn happens in a way that both exert force on each other, A needle model has been generated in Solidworks and then imported in Ansys workbench. Fatigue analysis of the needle has been done for flatbed and slantbed (at $\theta = 22.5^0$ and $\theta = 30^0$). Safety factor results are obtained for both flatbed and slantbed sewing machine, from which it is concluded that slantbed sewing machine needle has to experience lesser force compared to flatbed and has long life.

Keywords : *Needle, Fatigue, Ansys, Slantbed, Flatbed.*

Introduction

Industrial sewing is one of the most common operations in the manufacturing of garments, shoes, upholstery and technical fabrics for automobiles. Every day, millions of products ranging from shirts to automotive airbags are sewn using industrial sewing machines. Heavy industrial sewing, such as that used in the manufacture of automobile seat cushions, backs and airbags, requires not only high production but also high sewing quality (i.e. better appearance and seam strength). Typically, the material being sewn includes single and multiple plies of fabric or leather, sometimes backed with plastics, and needle heat-up is a major problem on the sewing floor. In recent years, in order to increase production, high-speed sewing has been extensively used. Currently, sewing speeds range from 1000-6000r/min. In heavy industrial sewing, typical sewing speeds range from 1000-3000r/min.

The subject of needle penetration force measurement has been studied by several researchers since the 1960‟s. The work focuses on two aspects: the development of instruments to measure penetration forces, and studies to relate the material, machine and needle variables to the penetration forces, needle heating and resulting seam damage. But fatigue analysis of sewing needle has not been conducted until now. It is totally a new approach to study the life of sewing needle.
In the 1970‟s, Hurt and Tyler have carried out extensive research work on this subject. The findings most relevant for this work have been - Finishing processes applied after manufacture modify the frictional properties of fabrics. Lubricants decrease the needle penetration forces required. Frictional properties have an influence on seam damage (the example given is for acrylic fibre that presents high inter-yarn friction, being thus prone to damage) (Hurt and Tyler,
1975).
Needle size is the main variable affecting mechanical damage (Hurt and Tyler,1976)
According to Blackwood and Chamberlain (1970), the damage produced on a fabric does not change significantly with thread in the needle, when comparing with a situation in which the fabric is stitched without thread. Regarding fabric finishing, Leeming and Munden (1978) have found that the force of penetration is critically affected by the use of lubricant or softener. The fabrics exhibiting high penetration values were also the fabrics which exhibited sewing damage when sewn using standard sewing tests. These authors contributed

decisively with the *L&M sewability tester (*US Patent 3979951, 1976), a device used in many studies on needle penetration force. This equipment simulates a sewing machine by penetrating the tested fabric with an unthreaded needle, at a rate of 100 penetrations per minute. A force measurement is taken and th e device counts the number of times the value is higher than a pre-set threshold. Although this situation is quite different from industrial operation, it allowed many laboratorial studies to be developed.

In recent work, Gurarda and Meric (2005) conclude that both pre-setting temperature and the finishing process have significant effects on the seam performance, needle penetration force and elastane fibre damage during the sewing of cotton/elastane woven fabrics.

Rocha (1996) related material and machine variables to the needle penetration forces. Among other parameters, bending rigidity and drape factor were found to influence needle penetration forces. The findings of other authors regarding the influence of fabric finishing on needle penetration forces were confirmed on a sewing machine, sewing at medium to high speeds. The phenomenon of needle heating during high-speed sewing, particularly important in the sewing of synthetic materials, is also a subject that has been studied by several researchers, e.g by Hurt and Tyler (1971). Recently Liasi *et al* (1999, 2001) presented a series of publications concerning the problems arising from this occurrence. Concerning the development of measurement instruments, there is also relevant research work to consider.

S.Simmons (1979) equipped a milling machine (for easier speed control) with a piezoelectric sensor and measured force during needle penetration into fabrics. The needle penetration force waveform obtained is depicted in Figure 1. As we shall see, this waveform is consistent with the results presented in this paper. Simmons made a detailed description of the whole penetration. Regarding needle withdrawal, he stated: “Needle shoulder is encountered [phase F] and a rapid increase of force ensues. Force is not as large as in zone A [penetration of eye] because a hole is already formed”. This statement is very important in the current work since it indicated that there may be some relation between the force values in the individual penetration phases.

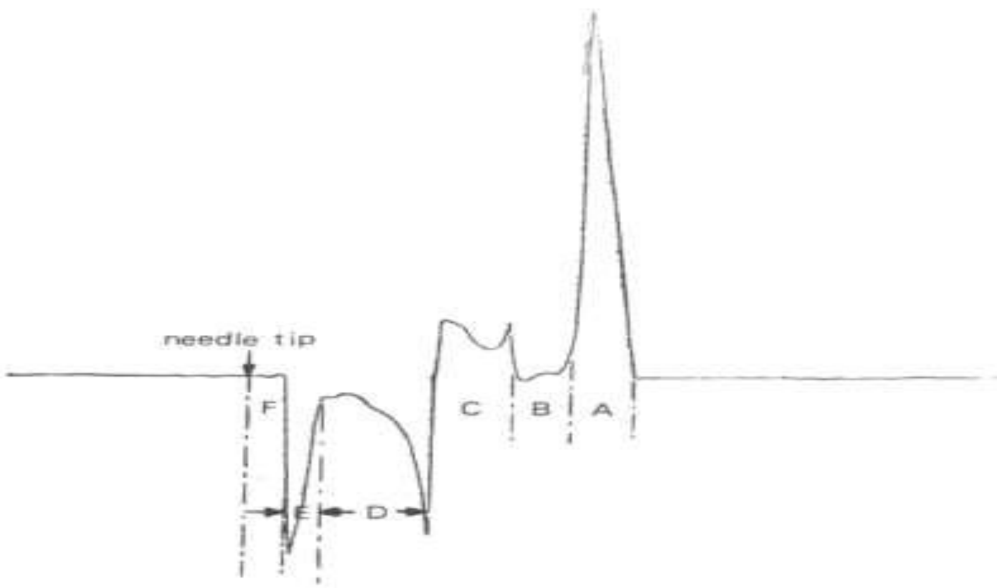

Figure 1: Needle penetration force waveforms found by Simmons (1970). Time-scale is inverted, penetration occurs from A to F.

Matthews and Little (1988) devised a sewing machine with sensors to measure force on the needle and presser-foot bar. The studies focused mainly on the study of the feeding system.

Mallet and Du (1999) proposed the use of finite element modelling techniques to predictpenetration forces into fabrics. Some success was achieved with this numerical technique,being the values within an 11% margin of those measured by a strain gauge applied to theneedle. The simulation used simplified models of the needle and a plain weave fabric.Figure 2 shows the typical profile of needle penetration forces predicted by Mallet. It is1 Nm:

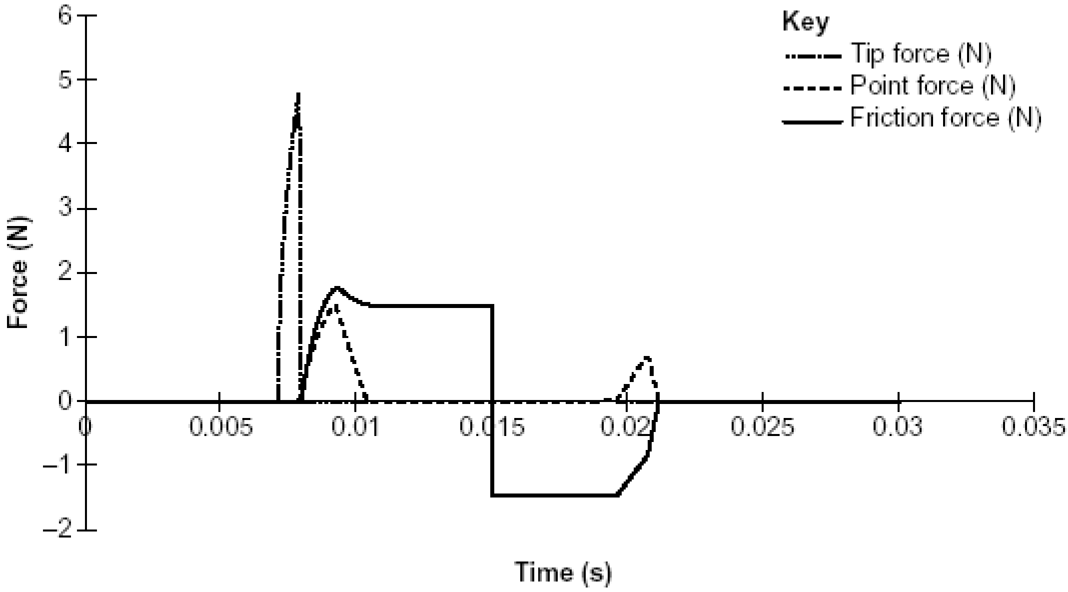

Figure 2: Needle penetration force profile predicted by Mallet with its FEM

Methodology

While many parts may work well initially, they often fail in service due to fatigue failure caused byrepeated cyclic loading. Characterizing the capability of a material to survive the many cycles acomponent may experience during its lifetime is the aim of fatigue analysis. In a general sense,Fatigue Analysis has three main methods, Strain Life, Stress Life, and Fracture Mechanics.

Strain Life is typicallyconcerned with crack initiation, whereas Stress Life is concerned with total life and does notdistinguish between initiation and propagation.WhileFracture Mechanics starts with an assumed flaw of known size and determines the crack's growthas is therefore sometimes referred to as "Crack Life". Facture Mechanics is widely used todetermine inspection intervals.

Stress life criteria has been used for fatigue analysis.

Constant Amplitude, Non-Proportional Loadingtype of cycling loading has been applied on the needle. Constant Amplitude, non-proportional loadinglooks at exactly two load cases that need notbe related by a scale factor. The loading is of constant amplitude but non-proportional sinceprincipal stress or strain axes are free to change between the two load sets. No cycle countingneeds to be done. But since the loading is non-proportional, the critical fatigue location may occurat a spatial location that is not easily identifiable by looking at either of the base loading stressstates.

Goodman theory has been used as shown below in Figure3.

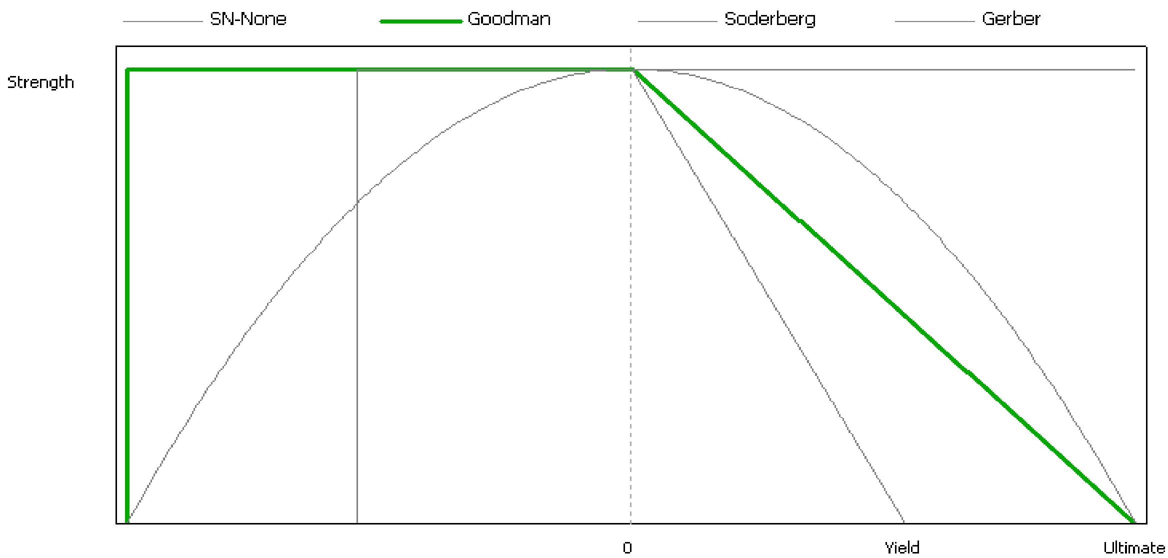

Figure 3- Theories for fatigue analysis

Approach and Input parameters

A sewing needle was modelled in Solids works and imported to Ansys for analysis. Different calculations of forces which a needle has to withstand, have been done for flat & slanted sewing bed at different angles. The geometries used are as following –

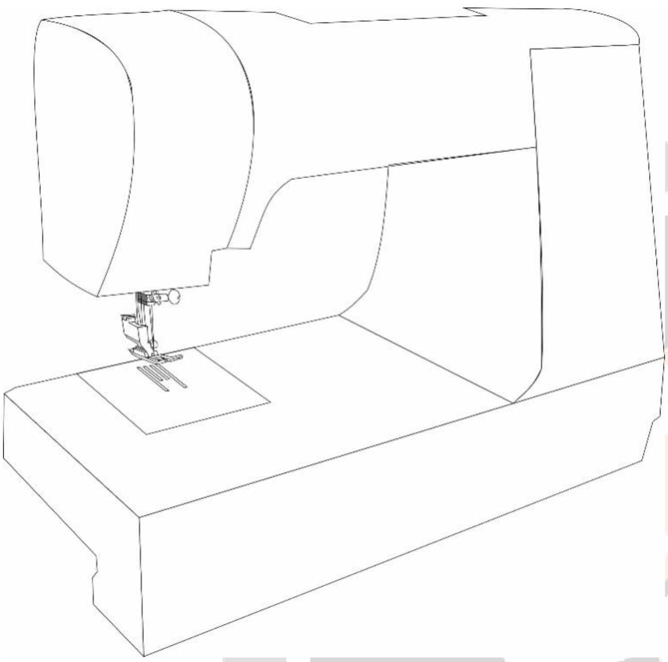

Figure 4(a) - Isometric view of Flatbed sewing machine

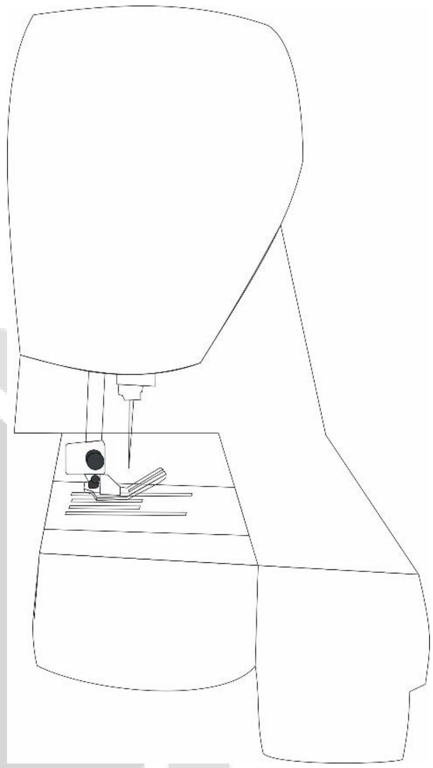

Figure 4(b) - Side view of Flatbed sewing machine

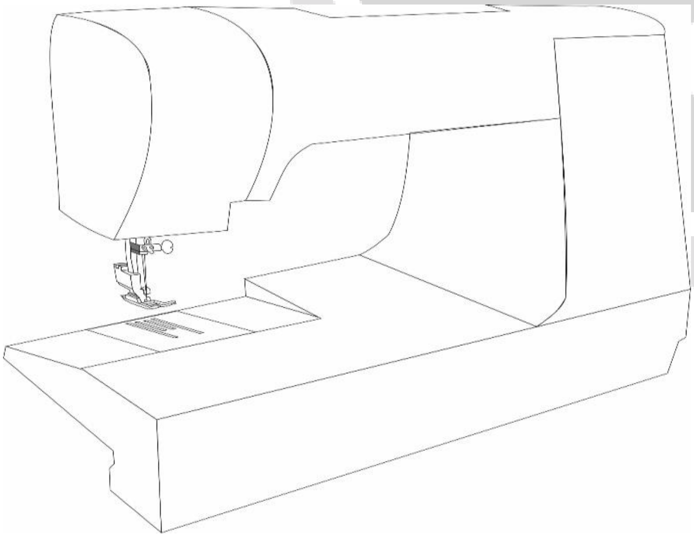

Figure 4(c) - Isometric view of Slantbed sewing machine

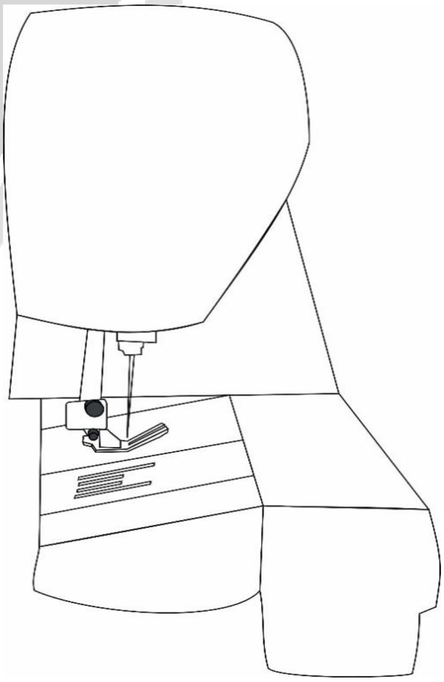

Figure 4(d) - Side view of Slantbed sewing machine

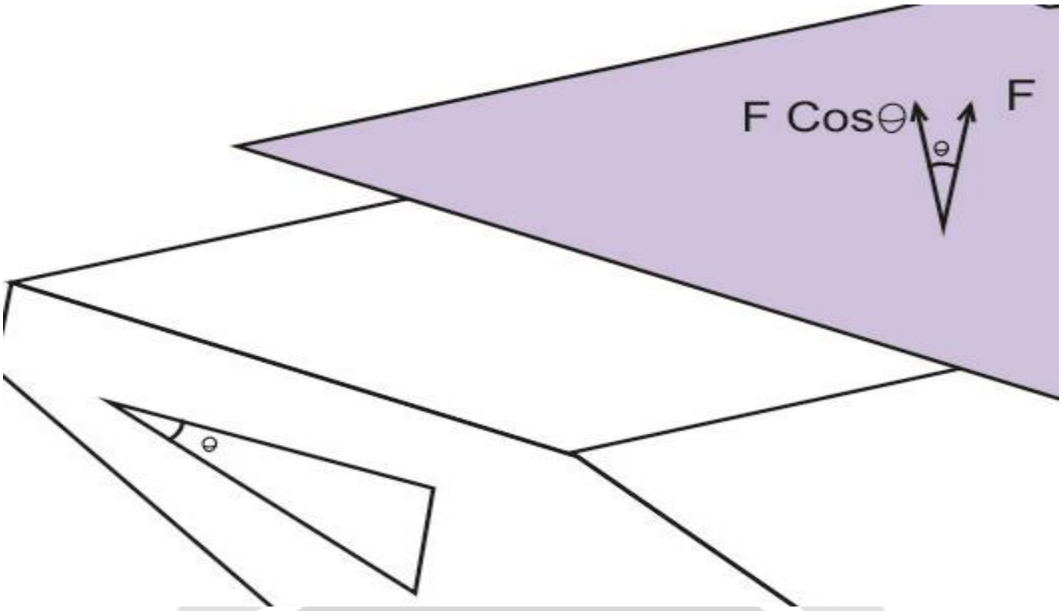

Figure 4(e) – Component of force due to bed inclination

Due to slanting of bed force on the needle get reduced by a factor cosθ. The value of force varies as the value of θ i.e. inclination of the bed is changed. Two values of bed inclination have been used in current analysis.

Needle Force, $F_N = F\cos\theta$

Where, θ is 22.5^0 and 30^0.

Boundary Conditions

The boundary conditions are kept same i.e. force on the tip surface of the needle in both the case of flatbed and slanted bed. Only the value of force has been changed with change in inclination of the bed

In case of flatbed

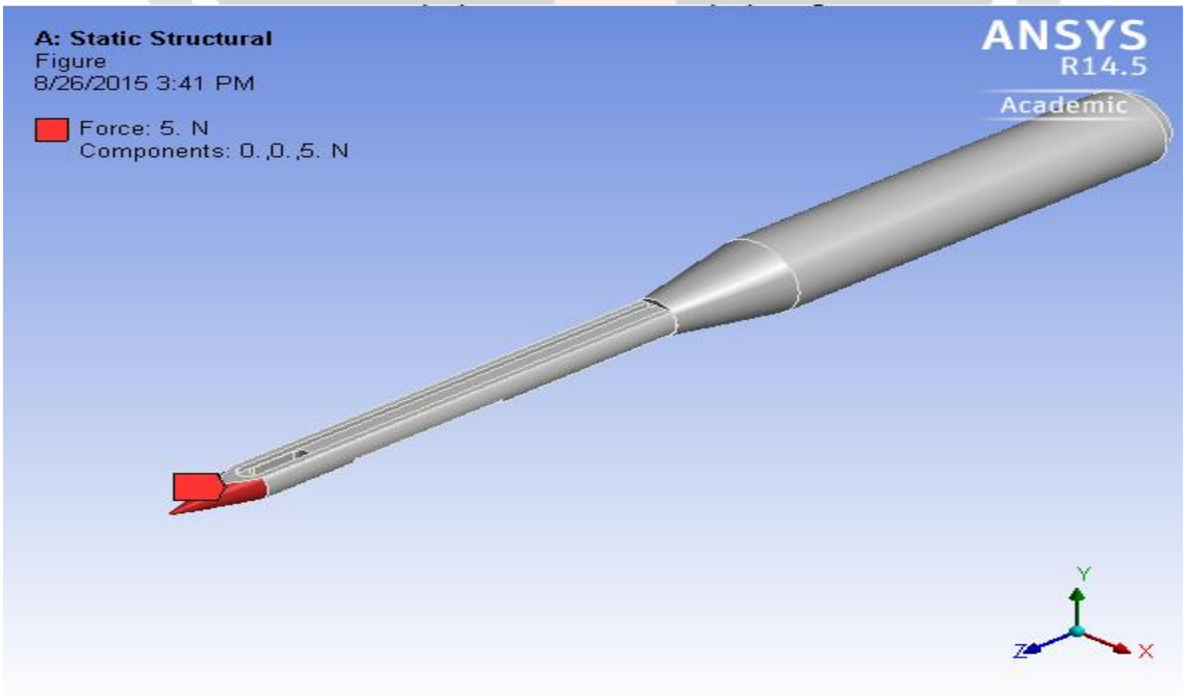

Figure 5(a) – Boundary Condition for Flatbed

In case of slant bed

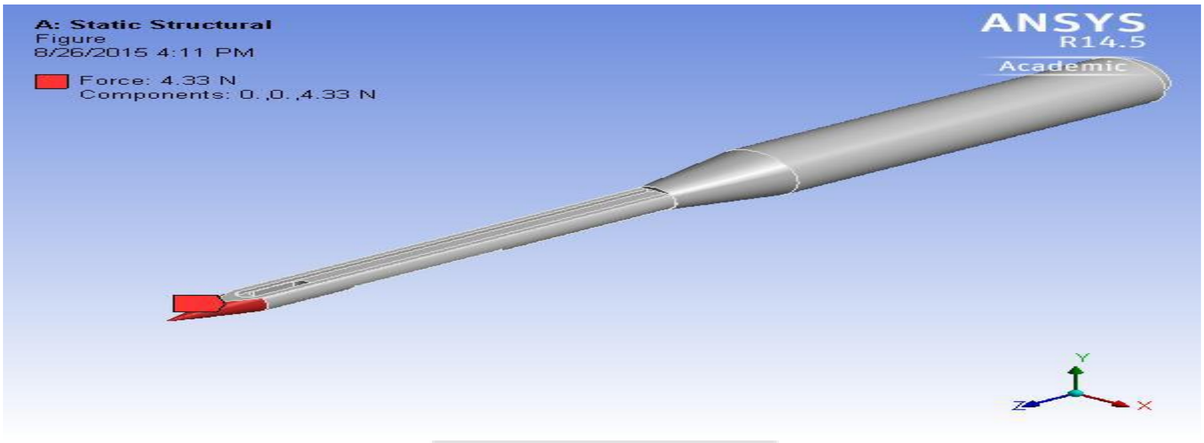

Figure 5(b) – Boundary Condition for Slant bed at θ = 22.5^0

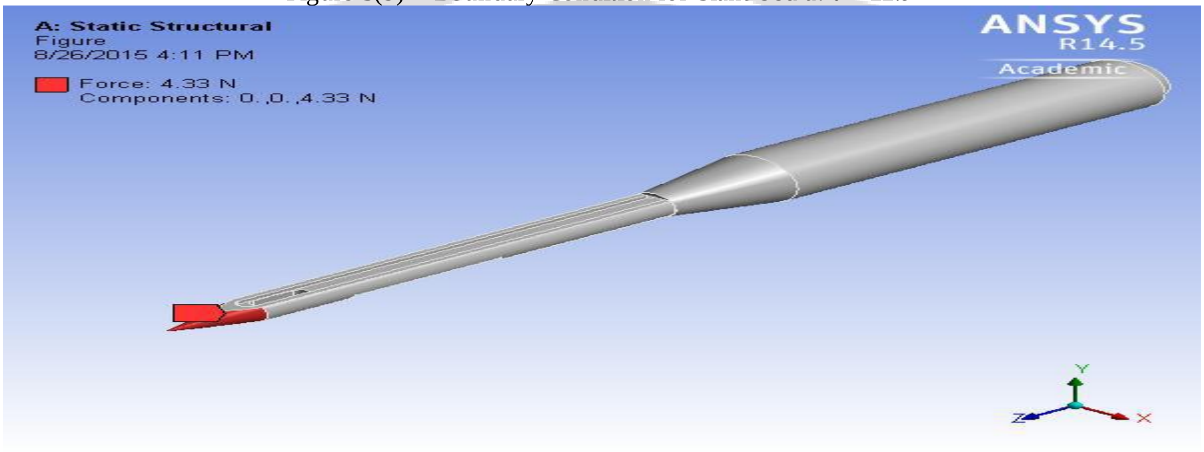

Figure 5(c) – Boundary Condition for Slant bed at θ = 30^0

Results and Discussions

Fatigue analysis of the needle has been done for a constant amplitude and non-proportional type of loading considering Goodman Criteria for alternating stresses. Different results for Safety Factor values are obtained, which shows that with slight inclination in the sewing machine bed reduces the magnitude of forces which a needle has to withstand during its functionality get decreased which in turn, increases the safety factor for the needle.

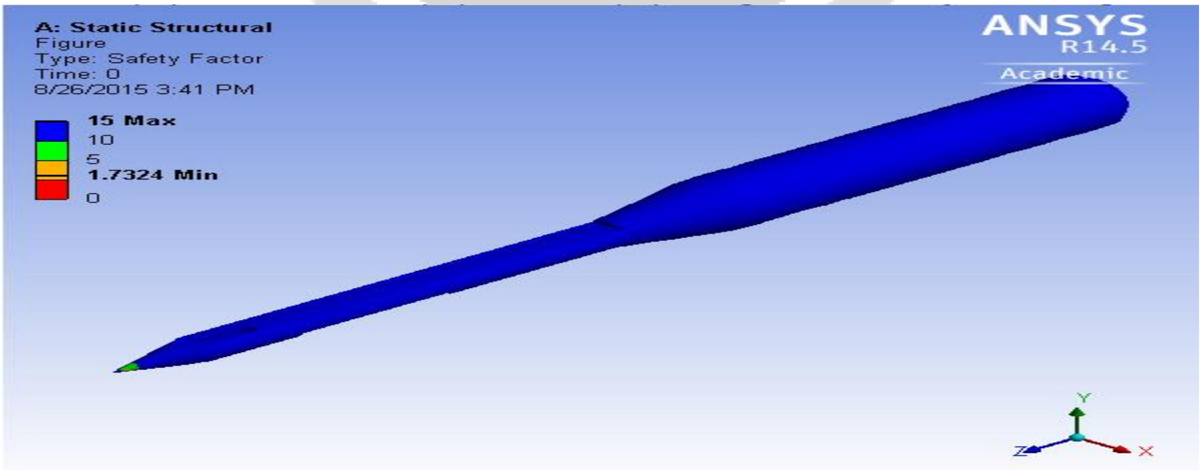

Figure 6(a) – Safety factor for Flatbed

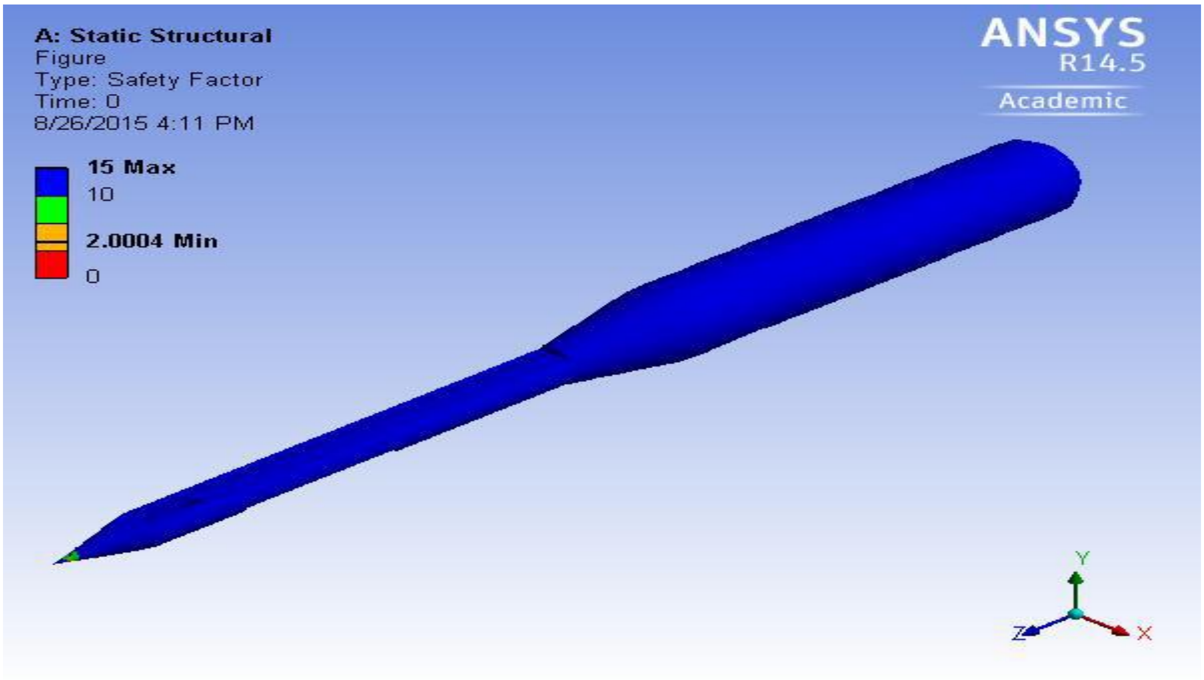

Figure 6(b) – Safety factor for Slant bed at $\theta = 22.5^0$

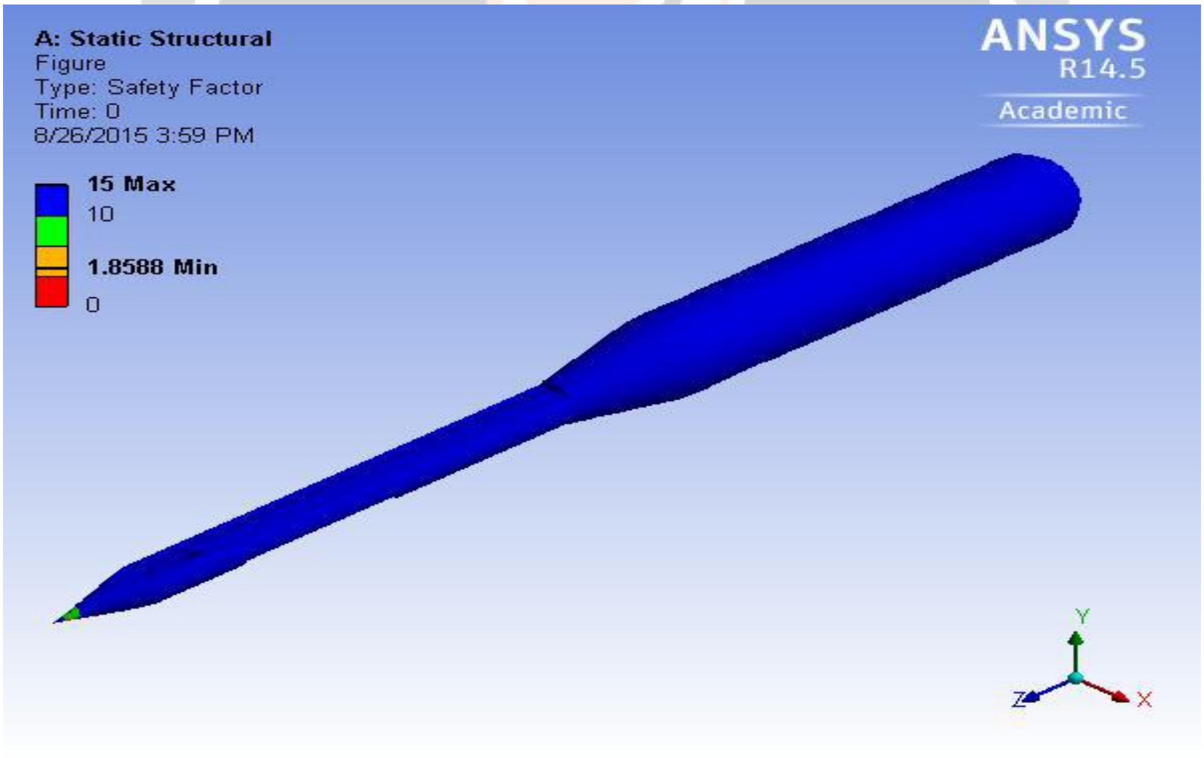

Figure 6(c) – Safety factor for Slant bed at $\theta = 30^0$

Conclusion

From the work done in this paper it is seen that by providing slight inclination in the sewing machine bed, a decrease in needle penetration force is experienced(needle penetration force get multiplied by a factor of $\cos\theta$). Due to which needle has to withstand a force of lesser magnitude and hence its life (no. of cycles without failure) get increased. It can be predicted from the results obtained for the safety factor under fatigue loading. The safety factor obtained for the sewing machine whose bed is inclined at an angle of 22.5^0 is maximum compared to flatbed sewing bed. Hence,it is concluded that Sewing machine having slight inclined bed will have more life, less damage.

References

1. Thaddens J. Zylbert et al., Stitch forming mechanisms for sewing machine, US Patent, Serial No. - 628704, 1956.
2. Nishigami et al., Sewing machine with slanted bed plate, US Patent, Application No. - 658183, 1976.
3. Carvalho, H et al, Measurement and analysis of needle penetration forces in industrial high-speed sewing machine.
4. Nader Khadamalhosseini, Mohammad Nasr-Isfahani, Masoud Latifi and Saeed Shaikhzadeh-Najar, “Modeling of Impact Damage of Sewing Machine Needle on Woven Fabric by Finite Element Method”Journal of Textiles and Polymers, Vol. 1, No. 1,pp 19 -23, January 2013
5. Sabria Gribaa, Sami Ben Amar, Abdelwaheb Dogui, “Influence of sewing parameters upon the tensile behavior of textile assembly” International Journal of Clothing Science and Technology Vol. 18, No. 4, pp 235- 246, 2006
6. Ezzatollah Haghighat, Saeed Shaikhzadeh Najar, Seyed Mohammad Etrati, “ The Prediction of Needle Penetration Force in Woven Denim Fabrics Using Soft Computing Models” Journal of Engineered Fibers and Fabrics Volume 9, Issue 4 pp 45- 55, 2014
7. Guanghui Xu, Yongbo Huang, Jun Deng, Taiyang Xu, “Design and Implementation of the Numerical Control Multi-Needle Quilting Embroidery Machine” Communications in Information Science and Management Engineering Volume 3, Issue 7, PP 310-314,2013.
8. Şerife Şafak, Ziya Şaka, Ziya Özçelik, “Modification of the Classical Needle Bar and Thread Take-Up Lever Mechanism in Sewing Machines” FIBRES & TEXTILES in Eastern Europe 2012, Vol. 20, No. 4 (93)
9. Daniela Zavec, Zvonko Dragevi, Dubravko Rogale, Jelka Geršak, “Investigations of the structure and process parameters of sewing operation” AUTEX Research Journal Vol 1, No.1, pp 39-46, 1999,