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Finite Element Analysis of Nylon 6,6 Polymer Rifle Magazine and Its Advantage over Sheet Metal Rifle Magazine

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Abstract: The study in the paper focuses on the material selection for the magazines used in assault rifles. A firearm magazine is a storage device that holds several rounds of ammunition and is attached to the firearm. The size of the magazine varies according to the number of rounds and the bullet size. The study aims to find an alternate material that can survive the harsh weather conditions of areas associated with India's National Security. Respective CAD models have been developed, and Coupled Thermal-Structural Analysis has been performed at 25 C, which is an average temperature and at a temperature of -57 C, which is the lowest temperature that is reached in the border areas. The stresses and displacement plots of the proposed material Nylon 6,6 are compared with the plots of AISI 1020 steel. The paper concludes the superiority of Nylon 6,6 material magazines over sheet metal magazines.

Index Terms **– Firearms, Magazine, Nylon 6,6, Coupled Thermal-Structural Analysis, Assault rifle**

I. INTRODUCTION

In India, due to vast variations in weather and demographic conditions, the design and material selection best suited for our varied climatic conditions is a major requirement. The climatic conditions in areas associated with national security and battlegrounds are way worse than the general areas. Hence, the equipment and arms used in such locations should be designed considering all the conditions. The paper focuses on giving a better alternative to the sheet metal magazine considering the harsh conditions like conditions on Siachen Glacier and can also be used in normal weather conditions. The material is selected on parameters like Tensile, Compressive and Yield Strength, the operating temperature of the material in which the part can operate without any failure, the frictional properties of the material and the necessary infusion to be made in the material, etc.

II. ASSAULT RIFLE MAGAZINE

The magazine is a major part of an assault rifle. It holds the rounds or bullets for the rifle and is attached to the 'magazine well' through which the bullets are fed into the rifle. As the bullets are fed into the rifle, a follower mechanism subsequently pushes the remaining rounds to the position where they can be easily fed. Magazines are reusable and are filled with bullets once emptied. Magazines for assault rifles come in various sizes, like 10 rounds, 20 rounds, and 30-round magazines. Majorly 2 sizes of bullets are used in assault rifles, 5.56 mm and 7.62 mm and the breadth of the magazines varies accordingly. The magazine has four major parts: Magazine body, Base, Follower and a Magazine spring. On the surface of the Magazine body ridges and indentations are present for better grip.

The model for a 5.56 mm, 30-round magazine was developed using SolidWorks. The assembly of the model includes 3 parts, namely: Magazine Body, Base and Follower.

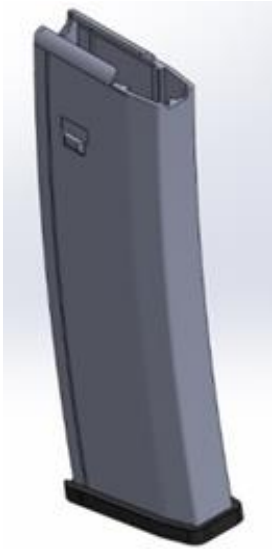

Fig 1: Magazine Assembly

III. EXTERIOR CONDITIONS

The magazine needs to deal with all the different conditions. Extreme high temperatures of +51 C can be found in the Thar Desert while freezing temperatures of -57 C can be found in the Siachen Glacier and Dras Sector. As the temperature decreases, the forces create a larger impact on the structure. Considering this scenario, the analysis is performed in two different conditions. The first is under normal conditions and the second is after applying the temperature of -57 C.

IV. MATERIAL

Sheet metals like AISI 1010 and AISI 1020 are widely used as materials for magazines. Though this material can withstand normal conditions, the same is not true with harsh conditions. Hence, the alternate material proposed is Nylon 6,6 with 10% glass fibre polymer. Following are the advantages of Nylon 6,6 with 10% fibre glass polymer:

- Outstanding dimensional stability
- Lower dry heat and steam shrinkage
- Better dye wash fastness and UV light fastness
- Higher melting point
- Higher tensile strength
- Excellent abrasion resistance

The infusion of 10% fibre glass provides Nylon 6,6 with better abrasion resistance which is required due to frequent insertion and removal of the magazine in the rifle. It also increases impact resistance, which gives the magazine an edge during any impact.

Table 1: Mechanical Properties of AISI 1020 steel and Nylon 6,6 with 10% fibreglass

Parameters	**AISI 1020 steel**	**Nylon 6,6 with 10% fibreglass (Proposed material)**
Density	7900 kg/m^3	1230 kg/m^3
Elastic Modulus	200 GPa	5 GPa
Shear Modulus	77000 MPa	1827 MPa
Poisson's Ratio	0.29	0.368
Tensile Strength	420.5 MPa	99.4 MPa
Yield Strength	351.5 MPa	95.2 MPa
Thermal Expansion Coefficient	0.15x10^{-6} /K	48.5x10^{-6} /K
Thermal Conductivity	47 W/mK	7.77 W/mK
Specific Heat	420 J/kgK	1290 J/kgK

V. COUPLED THERMAL STRUCTURAL ANALYSIS

Coupled Thermal-Structural Analysis is carried out when there is an addition of temperature with existing applied forces on the structure. In the following case, this analysis is performed on a nylon 6,6 with a 10% glass fibre magazine body and an AISI 1020 steel magazine body at -57 C and in normal condition. Forces of magnitude 50 N are applied inwards on the body. Results from both magazines are compared.

FEA Model

The magazine body is finely meshed with an element size of 2.5 mm.

Fig 2: Meshed Magazine

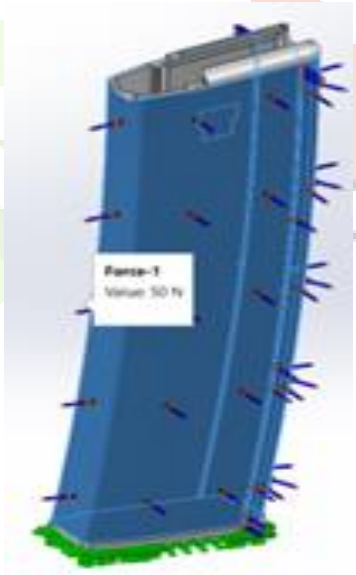

Fig 3: Force Application of 50N

Forces of 50 N are applied on the magazine body at temperatures of -57 C and 25 C for both Nylon 6,6 and AISI 1020 steel. The force of 50 N is selected because the max force a human hand can create is 45 N and in combat conditions, various forces get applied during the hasty insertion and removal of the magazine. Hence, the force of 50 N is applied in the analysis.

VI. RESULTS

a. Nylon 6,6 with 10% Fibreglass Magazine at -57 °C

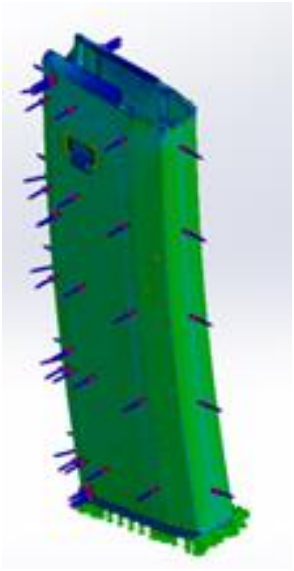

Fig 4: Stress Analysis of Nylon 6,6 with 10% fibre glass Magazine at -57^{O} C

Table 2: Result - Stresses on Nylon 6,6 with 10% fibre glass Magazine at -57 ^{O}C

Maximum Stress	**Minimum Stress**
4.082e7 N/m^2	1.302e5 N/m^2

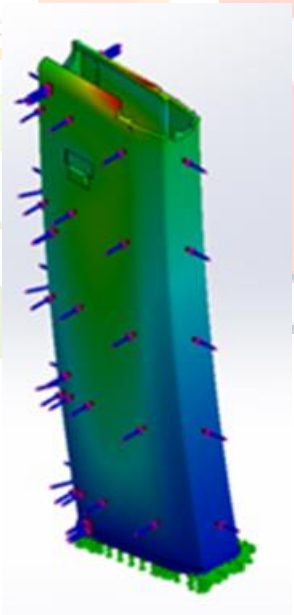

Fig 5: Displacement Analysis of Nylon 6,6 with 10% fibre glass Magazine at -57^{O} C

Table 3: Result – Displacement Analysis of Nylon 6,6 with 10% fibre glass Magazine at -57^{O} C

Maximum Displacement	**Minimum Displacement**
2.577e-1 mm	1.000e-30 mm

b. AISI 1020 Magazine at -57 °C

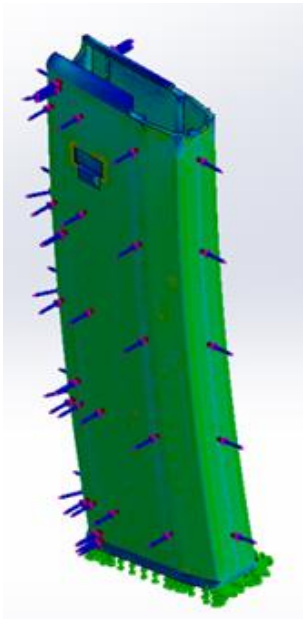

Fig 6: Stress Analysis of AISI 1020 Magazine at -57 °C

Table 4: Result - Stresses on AISI 1020 Magazine at -57 °C

Maximum Stress	**Minimum Stress**
4.419e8 N/m^2	1.727e6 N/m^2

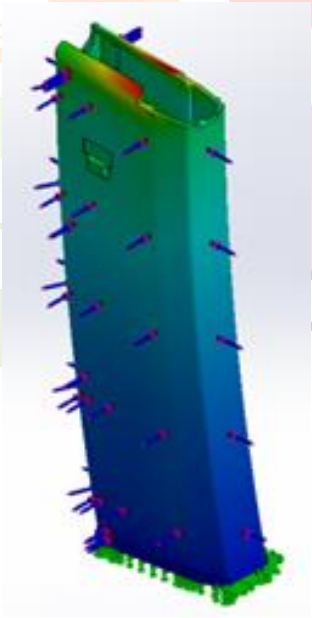

Fig 7: Displacement Analysis of AISI 1020 Magazine at -57 °C

Table 5: Result – Displacement Analysis of AISI 1020 Magazine

Maximum Displacement	**Minimum Displacement**
8.819e-2 mm	1.000e-30 mm

VII. COMPARISON

a. Stress Comparison

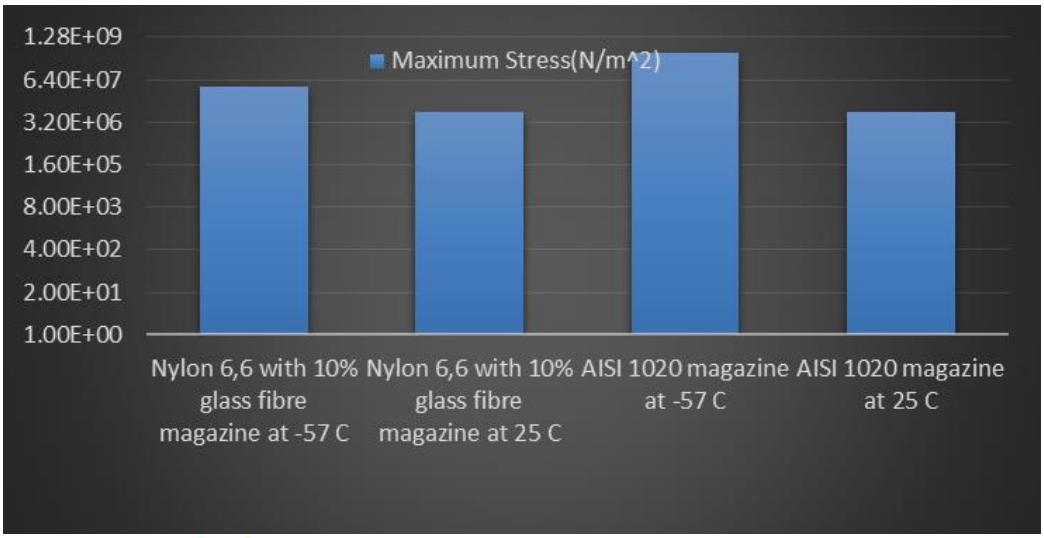

Fig 8: Stress comparison

b. Displacement Comparison:

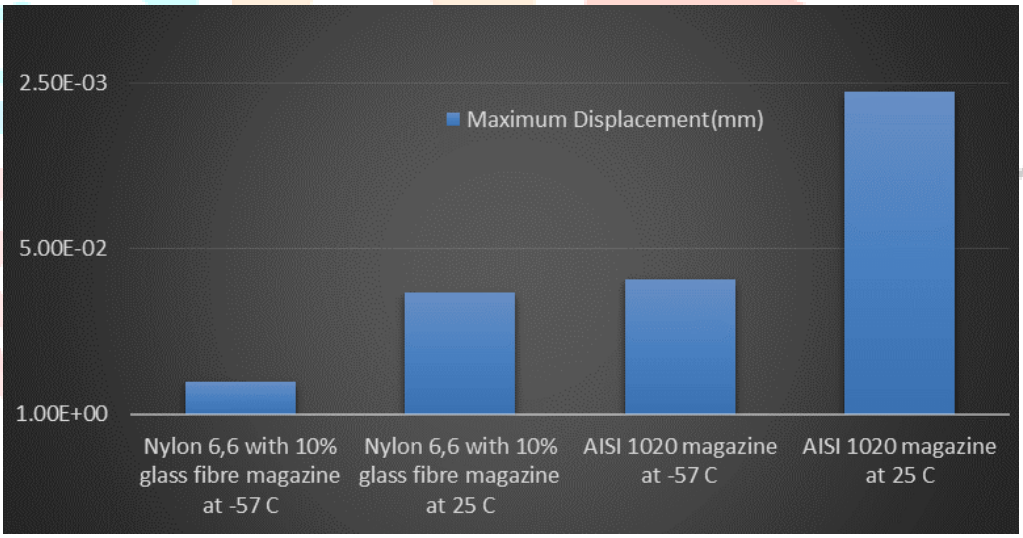

Fig 9: Displacement Comparison

VIII. CONCLUSION

From the above results, it can be concluded that though both the magazines stand well in normal temperature conditions, in the harsh conditions of the Siachen and Dras Sector AISI 1020 magazine develops stresses beyond its yield strength. This means the magazine will undergo plastic deformation under the loading condition. Hence, the chances of failure in sheet metal magazines are higher. But magazines made using Nylon 6,6 with 10% glass fibre withstand both conditions very well and no plastic deformation occurs. Hence, Nylon 6,6 with 10 % fibreglass magazines can be used as a singular alternative rather than sheet metal magazines.

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