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Woven steel mesh for usage in beds

A case study for IKEA

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4. Discussion

The modelling in Solid Edge constituted a big part of the study. Even though COMSOL has a modelling function, it would not provide the ability to model complex structures such as wires. Therefore, Solid Edge was chosen to be the modelling software for the problem. The simplification of the problem to not consist of rods and wires but only rods made the usage of Solid Edge yet more inefficient since the mesh consisting only rods could easily be modelled in COMSOL. Hence, the modelling in Solid Edge was not as beneficial as it was intended to be when performing the computations.

Since the project aims to examine whether meshed structures of metals are suitable for usage in beds, the study focused on certain relationships between Young's modulus and yield strength, plotted in figure 9. Steel was the preferred material in accordance with the stated hypothesis and even the set material selection for the reference model. Therefore focus was set on all types of steel primarily.

When taking economic aspects into account in figure 10, it is noticed that steel provides the cheapest metallic alternative for usage in metal mesh. Even though steel generally poses a cheap profile, stainless steel is a remarkably much more expensive alternative. With a price ten times bigger than that of standard steel, stainless steel is from an economic perspective considered to be an expensive solution for this purpose. Corrosion resistance is also considered an excessive property for these kinds of applications and consequently the choice was made to exclude stainless steel types for usage in beds in this study.

The analysis of the relationship between yield strength and economic aspects, a new metallic option was discovered. As mentioned in the hypothesis of the project, earlier only solutions with steel types were considered. Although, it was observable that aluminum is making an alternative solution for a span of yield strengths until about 600 MPa. Hence, aluminum was included into account in the study when analyzing solid mechanic behavior of the mesh.

It is observable in figure 11 that metal mesh made of steel fulfills the requirements set on displacement and prohibition of plastic deformation since all maximum von Mises stresses exposed on the rods are below 1500 MPa, which is the upper limit for yield strengths' of the most common sorts of steel. Since standard steel has an upper limit around 1500 MPa for yield strengths, rods with a radius under 2 mm is not meeting the requirements set by plasticity conditions although the displacement is under 20 mm for smaller radii. Thus, meshes made of steel must have a rod radius above 2 mm.

General properties as total price and total weight for steel are plotted and analyzed in figure 12. These properties are an important part of the marketability of a product. It is concluded that rod radii must lay above 2 mm. Rod radii over 2 mm generate a total weight of about 20 kg and the total price is consequently around 75 SEK. These values are therefore the minimum price and weight properties to be expected by mesh made of steel.

Analogously with the representation and analysis of the mechanical properties of steel mesh, results calculated for aluminum were plotted in figure 13. As discussed earlier, aluminum has an upper limit for yield strengths around 600 MPa. When taking this into account and integrated with the results from solid mechanic calculations, it is observed that rod radii must lay above about 2.75 mm. Unlike steel, aluminum does not fulfill the requirements set on displacement for all radii. Radii beneath 2 mm generate displacements over 20 mm as seen in the plot. Thus the plasticity properties are the deciding factor for aluminum mesh.

As for the general properties of aluminum, it is seen in figure 14 that for a radius of 2.75 mm the mesh has a total weight of about 10 kg and a total price of about 150 SEK. Analogously with steel mesh, these values constitute the minimum limit for a mesh made of aluminum.

There are only 3 differences between steel and aluminum when computing in COMSOL. These differences are the values of density, Poisson’s ratio and Young’s modulus of elasticity. Thus, it is seen in figure 16 that these only affect the deformation curve by a relocation vertically upwards. This strengthens the correctness of the approach made in chapter 2.2.3. Small deviations in the Young’s modulus will not alter any remarkable differences in the deformation behavior, thus the approach of selecting the Young’s modulus of an average 200 MPa was proven to be accurate for the computations. Only when the deviation is big enough, such as in the case for the difference between aluminum and steel, the deformation curve will be affected, and this only by a relocation vertically as once again seen in figure 16.

Generally, it is concluded from the results from chapter 3.2.1.3 that both aluminum and steel fulfill the requirements when discussed for different span of rod radii. Although there are some parameters that distinguish a possible material selection out of the two, such as weight and price. Steel provides a cheap but yet very heavy solution for the purpose, whereas aluminum doubles the price and halves the weight. In this matter, the authors of this report consider weight to be the deciding parameter when selecting the most suitable material. This because of the individual transportation of the package containing the mesh and additional contents of the bed when buying the intended product.

Figure 19 displays the results of the calculations regarding the rolling properties. An approximate gap of 2 mm between each turn has been used which allows for certain margin of error. A steel rod radius of 2 mm will generate a roll with a width of about 145 mm while the aluminum radius of 2.75 mm generates a somewhat thicker roll of 155 mm. Both roll widths are reasonable for storage and transportation purposes and can easily fit into a package. In this manner, it is once more important to note that a roll width of circa 150 mm means that the metal mesh will be delivered in rectangular packages with the dimensions of about 900*150*150 mm^3. When the weight of the metal mesh is taken into consideration, it is seen that weight is the one parameter that should be considered carefully when determining the best suitable material.

4.1 Source of errors

- **Wire**

  The biggest source of errors in this project is the assumption made in chapter 2.1.2 that the wire has no effect on the solid mechanic behavior of the metal mesh. This assumption is made as mentioned earlier based only on consultations with Professor Bo Alfredsson. Thus the credibility of this assumption lays totally on Alfredssons's perception of the problem. The problem lays within the consultation itself since Bo had not enough time to analyze and thoroughly think through before giving his advice. He only could give advice based on his first impressions of the problem as he himself explained.

  The absence of the wire is also affecting the results on weight and rolling properties directly. The presented total weight calculations do not include the weight of the wire. It is even clear that the stiffness and thickness depending on the material selection of the wire will influence the rolling properties.

- **Distribution**

  The distribution of the rods were only based on the reference model in which it was 10 mm. It is a source of error to not study the optimization of the distribution when varying the rod thickness. This because the thickness of the rods correlate with improved solid mechanic properties. Thus, a more sparse distribution could be studied for thicker rods and a relationship between minimum required distribution and rod radius could have been designed.

  When the distribution is locked to the reference model and the conditions set by IKEA, the mesh always contains 200 rods totally. An optimization of the distribution would decrease this total amount of rods and accordingly the total weight as well as total price could be reduced to minimum values, making it a source of errors in manner of optimization for the stated purpose of usage.

- **Fixation**

  The examination of fixation points for a rigid body is a specific area in solid mechanics which would require an entire study in itself. The fixed constraint used when performing the calculations is a simple way to simplify the complex problems that fixation points cause. Fixation is affecting the solid mechanic behavior of a body directly by generating nodes in the fixed points. Hence, this behavior is not considered in this study because of the usage of the simple 'fixed constraint' application in COMSOL.

5. Conclusion

- Aluminum fulfills criteria set on plasticity and deformation. Thus steel is not the only option.
- It is concluded that weight is a more important parameter to consider. Aluminum is the recommended material of choice based on the results discussed.
- The mesh is generating a roll of at least circa 90 mm thickness, which is concluded to be a reasonable dimension for a manageable package.

5.1 SWOT-analysis

Below follows a SWOT- analysis made on the product that has been examined and concluded to fit best for the aimed usage.

Table 3 SWOT Analysis of metal mesh of aluminum

Strengths	Weaknesses
• Light weight • Recyclability • Durability • Ability to be rolled	• Expensive • Relatively thicker rods required • Chatter • Fatigue of load bearing components
Opportunities	**Threats**
• Easy production • Coating and/or surface treatment to avoid chatter. • Reusability of certain component or whole mesh • Wide range of fixation possibilities	• Unpredictable price fluctuation of raw material • Weak competitiveness against current cheap solutions on the market • Low awareness of existence in the furniture branch

6. Future Studies

Since the wire had no effect on the solid mechanic behavior of the mesh, it was excluded while performing the calculations. Although the impact of the wire on the solid mechanics is a suggested area of future studies. The examination of the metal mesh including the linking wires would provide more adequate and accurate results for the final analysis of the product.

There are many aspects that could be a subject for suggested future studies such as an investigation of finding suitable material suggestions for the wires, solid mechanic impact of the wires on the metal mesh and also the acoustics. Since the wires are in constant contact with the metal rods, this contact will generate chatter. Chatter can be decreased by several techniques and hence it is a wide area of possible future studies. In this study, some surface treatments and coatings have been briefly presented. Thus a parallel investigation of a suitable non-metallic or metallic material for the wire could be studied, in which acoustic and solid mechanic aspects are included.

As mentioned in the report, the science of fixation for rigid bodies is a deep and wide area of solid mechanics. Since this study has chosen to not consider fixation, it is suggested as an important and natural continuation. It is also important since the solid mechanic behavior of a loaded mesh will have a direct dependency of the fixation. Furniture’s comfort depends very much on its durability in general where all kind of aspects that will influence must have been optimized for the certain purpose. Thus, fixation is one of the major future study areas.

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