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P2_5 The knitters dilemma

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Abstract

In this paper we calculated the total length of time a knitted jumper has to be worn to balance out the energy used in creating the jumper. Experimental values were found for the length of time to knit a jumper. The amount of calories burnt per hour of knitting and the time taken were then used to calculate the overall energy used. The rate of heat loss was calculated for a thin cotton t-shirt and for an aran weight jumper before the total length of time it would have to be worn to make back this energy was calculated. We have found that the amount of energy taken to knit a jumper is $1.10\text{x}10^7 J$ and the jumper would have to be worn for 3 hours to balance this energy.

Introduction

The jumper discussed uses $600g$ of aran weight yarn knitted on 5mm needles, we have followed the pattern for a medium male [1]. For the purposes of this paper it was assumed that the yarn was 100% wool. The jumper was assumed to be knitted entirely in stocking stitch. Stocking stitch is a style of knitting where rows are done in alternate knitting and purling rows. A knit stitch is a done with the needle going into the front of a stitch, while a purl stitch is done with the needle going into the back of the stitch. Yarn comes in 8 main thicknesses, with aran weight being the 3rd thickest.

Energy used creating a jumper

The energy used in wool production is $8MJ$ per kilogram [2].Therefore the energy required to produce our $600g$ is $4.8MJ$. We are neglecting the energy taken to get the wool from the factory to our front door. To find the energy used in making a jumper, values of the time taken for rows of knitting and purling were found experimentally and an average value was found. The average was divided by 99, the number of stitches in a row, to find the average time taken to make one stitch. The average time for a singular knit stitch is $2.55 \pm 0.1s$ and for a purl stitch is $3.05 \pm 0.1s$. In the pattern there are $2.44\text{x}10^4$ knit stitches and $2.40\text{x}10^4$ purl stitches [1]. It is therefore calculated that the jumper would take $1.35\text{x}10^5$ seconds. We have added an extra $1.8\text{x}10^4$ seconds onto this figure to account for the time taken to sew the jumper up. This value was found experimentally. The total length of time taken to make the jumper is therefore $1.53\text{x}10^5$ seconds or 42.5 hours. An average human weighing 70kg burns $40.4J$ per second of knitting or light sewing [3], meaning that the amount of energy used for the jumper is $6.18\text{x}10^6 J$. This value is added to the amount of energy used in production of the wool to find the total value of the energy used in hand knitting a jumper. The total energy used up in making the jumper is therefore $1.10\text{x}10^7 J$. This is process can be seen in equation 1.

$$Q_{tot} = Q_{production} + 40.4(t_k N_k + t_p N_p + 1.8\text{x}10^4) \quad (1)$$

where Q_{tot} is the total energy used in making the jumper, $Q_{production}$ is the amount of energy used in the production of wool, t_k and t_p are the time taken to knit a stitch purl a stitch respectively and N_k and N_p are the number of knit stitches and number of purl stitches.

Energy saved wearing a jumper

We calculated the efficiency of the jumper by calculating the rate of heat loss wearing a cotton t-shirt and the heat loss wearing a wool jumper. We then found the difference between these two values to find the amount of energy per second saved by wearing the jumper. The rate of heat loss is calculated using equation 2 [4].

$$h = \frac{-kA\Delta T}{x}, \tag{2}$$

where h is the rate of heat loss , k is the thermal conductivity, A is the surface area, T is the temperature and x is the thickness of the cloth. k_{cotton} and k_{wool} are 0.029 and 0.038 respectively [4]. x_{cotton} and x_{wool} were found experimentally and are 0.001 ± 0.001m and 0.005 ± 0.001m respectively. To find the surface area used in equation 2, the torso and arms of a human are modelled as a cuboid with dimensions of 0.45m x 0.67m x 0.24m with two cylinders attached of length 0.60m and circumference 0.26m. These measurements have either been taken from the pattern, or from experiment [1]. The surface area of the upper body is therefore found to be 1.45m^2. The temperature difference is the difference between body temperature 37°C and the average UK winter temperature 5°C. The rate of heat lost through the cotton t-shirt is therefore 1346Js^{-1} and the heat lost through the wool jumper is 353Js^{-1}. The negative sign can be neglected as that shows us that there is a heat loss. Using equation 3 the length of time needed to wear the jumper to balance the energy used in making it is found.

$$h_c - h_w = \frac{Q_{tot}}{t}, \tag{3}$$

where h_c and h_w are the heat lost by cotton and wool respectively, and t is time. The time for the jumper to be worn to balance out the energy used in making it is 1.11x10^{4}s which is the equivalent of 3 hours. Therefore to balance out the energy taken to make a jumper, it would have to be worn for less than a working day. This is a reasonable length of time for a jumper to be worn, and so the knitter need not worry that the energy spent making a jumper is wasted energy.

Discussion

All jumpers are obviously not made from 600g of aran weight wool, thinner wool would take more energy to knit up, would also take more wool and would not insulate the body as much. Therefore a thinner jumper would have to be worn for a longer period of time to make back the energy used in its production. Similarly a thicker wool would take less time and would be more insulating. The size of the jumper made would also have an effect on the length of time it would have to be worn to make back the energy used up. The medium male jumper was used for this paper as it was the project our amateur knitter was working on. Further research could investigate the relationship between the size of jumper and the amount of energy used in production. The results could also be improved by averaging the time for one stitch over more rows to find more accurate results. The amateur knitter used in this paper does not necessarily knit at a standard rate and therefore future work could be done to compare different knitting speeds to find the optimum speed to knit at to reduce energy consumption further.

Conclusion

We have shown that the energy used in making a jumper is not wasted energy as after being worn for 3 hours the amount of energy saved by the wearer becomes greater than that used in making it.

References

[1] https://www.loveknitting.com/breton-mens-sweater-in-paintbox-yarns-simply-aran-downloadable-pdf [Accessed 24th October 2017]

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[3] http://calorielab.com/burned/ [Accessed 24th October 2017]

[4] http://www.physicsclassroom.com/class/thermalP/Lesson-1/Rates-of-Heat-Transfer [Accessed 24th October 2017]