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Fabrication of Belt for Backpack for Students to Reduce the Musculoskeletal Disorders Using ABS Material 3D Printing

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Abstract

In the present study, the design and development of a composite-based belt aim to reduce the excessive burden on the backs of schoolchildren, which often leads to musculoskeletal disorders (MSD). The belt is designed using CATIA 3D modeling software and fabricated on an FDM-based 3D printer with ABS polymer. The design process focuses on addressing physical stress caused by heavy backpacks and prolonged use of electronic devices, both of which contribute to MSD. The analysis conducted through simulation on ANSYS software reveals significant reductions in stress on the shoulders and knees, allowing for more comfortable movement for students. The belt helps redistribute the weight from the shoulders to the lower back, thereby reducing strain on the upper body. The fabricated belt exhibits properties that are compatible with standard school bag materials, making it a feasible and practical solution for schoolchildren. Moreover, the product design was optimized through ergonomic analysis, ensuring that it fits comfortably and functions effectively in reducing physical strain. The belt's ABS-polymer material ensures durability, strength, and ease of manufacturing, all of which are essential for regular use in school settings. The analysis also showed a reduction in shoulder stress by approximately 1.50 MPa and in knee stress by 1 MPa under a typical load of 5 kg, demonstrating the belt's effectiveness in alleviating stress. This research presents a promising ergonomic intervention for reducing musculoskeletal issues in students caused by carrying heavy backpacks.

Keywords: Heavy back packs, ABS, 3D printing, structural modelling, ANSYS

INTRODUCTION

Ergonomics or human machine design is the inductive science that deals with the relationship between man and his environment at the place of work. The term climate Definition includes the tools and all the materials, the strategy for work, the climate at the place and the climate of the work as well as the working organization of it. From the above argument it would mean that ergonomics is the science which deals with the interaction of man and his tool or equipment and the surroundings. While ergonomics corresponds to the concepts of anthropology, biomechanics, and physiology, it deals with man's daily work. The expectation is to be able to fit the working equipment and or workplace to the man, then fitting the man to the job.

Work-Related Musculoskeletal Disorders (WRMSDs) occur when the physical limitations of the agents do not accommodate the physical requirements of the action and affect students in the workplace. If work tasks and equipment are not designed in accordance with ergonomic principles, employees are exposed to needless physical strain,

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awkward positions, strenuous efforts, monotonous development, and difficult work. Understanding ergonomics in the workplace can improve the work plan consistency. Ergonomics is the study of how people use equipment to perform specific tasks and ensure compatibility between people and their work. It prioritizes people by assessing their capabilities and limitations. In 2003 for instance students were discovered to be carrying 30 to 40 percent of their body weight in the knapsack loads that they brought to school. It should be noted that this case study findings, although no standard's (around max load) had been set in order to avert back aches showed only 10 percent of the child `s bodyweight is required as maximum. The following year individual study [2]. showed some findings and pretentious statements and did not seek solutions: most of the loads dispensed in children's research are considered excessive and optimal 10- 15% of body weight in young kids is recommended as safe and optimal for torsional stress. Since these surveys, more recent evidence reports that these loads are not as heavy and indeed have been attempted by some with varying carrying loads of children from 10 upto 25 percent of normal bodyweight in depending on each specific level of the growing process [3,4,5,6,7,8,9,10,11]. Among students' daily school bags, workstations with books, pencil cases, logical adding machines, sportswear, school day clothes and groups, game-specific preparing outfits and game-specific footwear, lunch boxes and full bottles of water [12]. According to Mackenzie et al., [1]. it was suggested that coming up with school storage areas will enable students to avoid having to carry backpacks which must have nearly all these items. However, owing to the destruction of the places and insecurities, schools have in the recent past eliminated storage zones [13]. Burdens might be on the increase because of the increase in the size of school knapsacks and the weight to be carried resulting from changes in the school educational plan such as; more assignments are being given and more after school or extra curricula activities and the carriage of new emerging items such as PCs [14,15,16]. The correct position of ergonomics of school bag has been illustrated in Figure 1 and parts label associated with the improvement of the bag has also been identified.

The present investigation deals with the synthesis of belt using 3D printing with polymer and its simulation on ANSYS software which aid in the appropriate manufacturing of the product.

DESIGN OF BELT BY USING ANTHROPOMETRIC DATA & (DOE) TECHNIQUE

The Taguchi method, a robust Design of Experiment (DOE) technique, was employed to optimize the belt parameters. This method allows for a systematic and efficient way of studying the impact of multiple factors and their interactions with minimal experimentation. The three parameters selected for this study—BH, BW, and SSW—were assigned three levels each, as outlined in Table 1.0 The levels for each factor were set as follows:

- Belt Height (BH): 25 cm, 30 cm, 35 cm
- Belt Width (BW): 20 cm, 25 cm, 30 cm
- Shoulder Strap Width (SSW): 7 cm, 9 cm, 11 cm

Table 1. Factor and Levels for the Belt Design and Development (unit-cm).

Factor	Code	I	II	III
Belt Height	BH	25	30	35
Belt Width	BW	20	25	30
Shoulder Strap Width	SSW	7	9	11

These levels were chosen based on preliminary research and ergonomic guidelines to ensure that the belt design could accommodate different body sizes and preferences while maintaining functionality and comfort. An L9 orthogonal array was selected for the experimentation, which is a standard array in the Taguchi method for studying three factors at three levels. The L9 array allows for the examination of each factor at all levels, without needing to test all possible combinations, thereby reducing the number of experiments needed from 27 (3^3) to 9. This array provides a balanced distribution of factor levels across the experimental runs, ensuring that the influence of each parameter can be independently assessed. The Taguchi method proved to be an effective tool for optimizing the belt design parameters.

Figure 1. Bag design ergonomics [17].

MATERIALS AND METHODS OF DEVELOPMENT

ANSYS Modelling

The article aims to develop a special belt which aids to support the excessive loads of the book on the school bag of the children. The agronomics is selected using the simulation results and the fabrication is done using 3D printed polymer material. The preliminary design was made on CATIA software, Figure 2 shows the necessary views of the initial design

The model of the bags was transported to the ANSYS for the simulation of the stresses prevailed due to the load on the shoulder of the children. For the preliminary analysis the weight on the shoulder is taken as 5 kg and the stress analysis was done. The file is next transfer to the ansys structural module for the analysis of the stresses. The file is then meshed with the necessary precautions and the boundary condition of weight and fixed support is applied on the desired location to get the appropriate result. Figure 3 shows the boundary condition and messing of the proposed model.

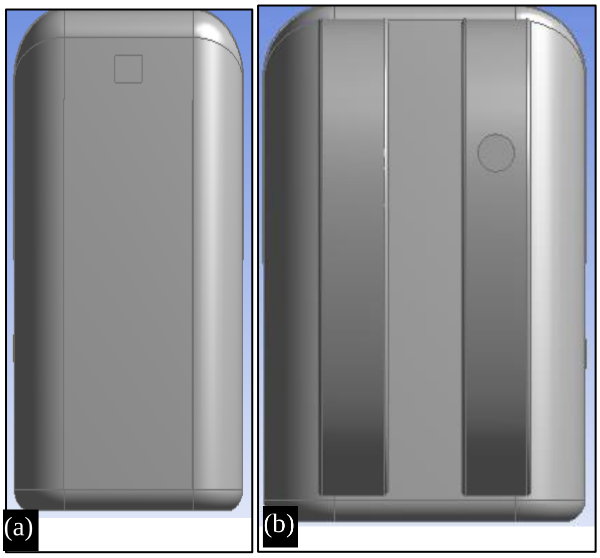

Figure 2. Solid Model of proposed belt on the bag of student.

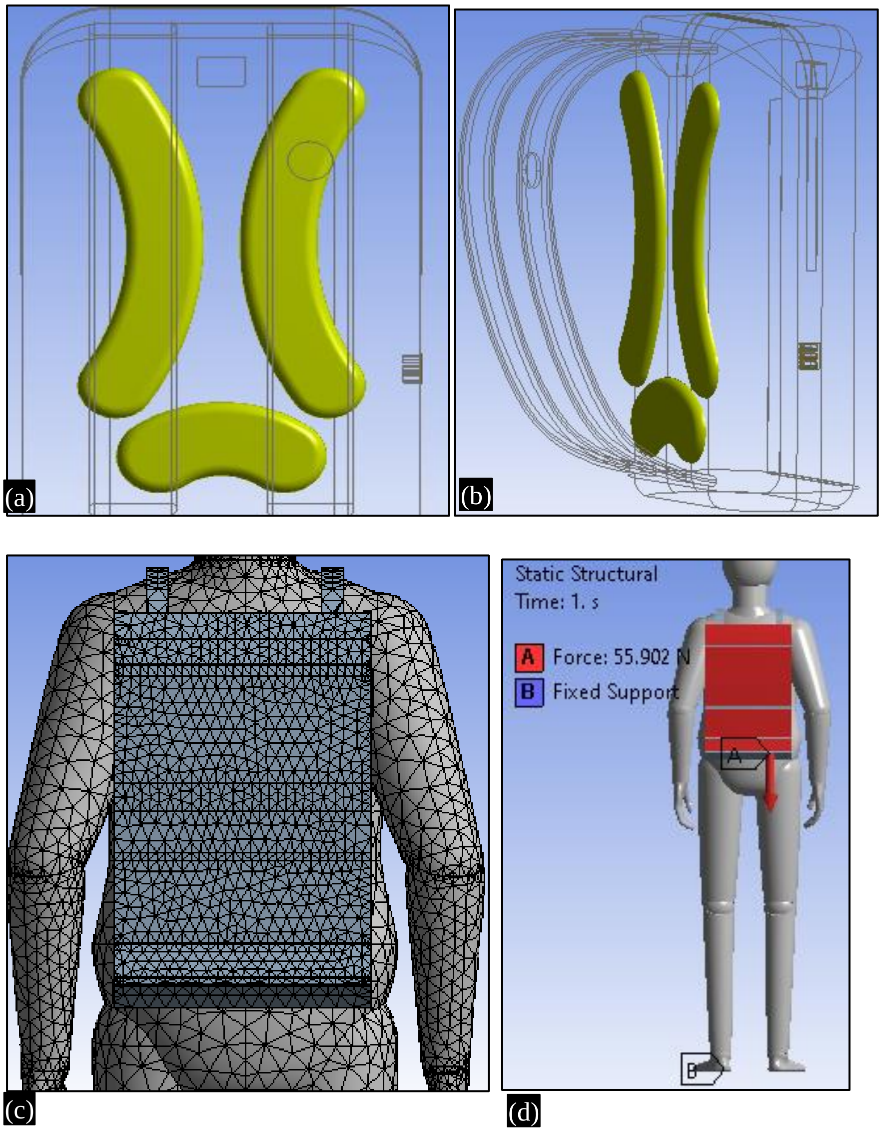

Figure 3. Ansys simmulation (a), (b) Model (c) mehing (d) boundary conditions.

3D Printing by using ABS material in FDM

As an additive manufacturing approach, 3D printing has become a viable way to fabricate engineering components, in contrast to many other production procedures. This makes the technology appropriate for industrial use because of some of its advantages such as reduced wastage of materials, ease of production, low labour intensity, minimal need for post-processing, and efficiency in energy consumption. Relative to part complexity, fabrication time, and prototype flexibility, 3D printing technology is a rising technology in the field of polymer composite manufacture. Using appropriate 3D printed composites instead of conventional replaceable parts has proven to be more efficient and cost-effective, especially in the automobile and aerospace industries. The model of the proposed belt is fabricated using Sincgrid 3D Printer (Industry Grade) with following Specification:-

a. *Type*:- FDM- Fusion Deposition Method
b. *Extruder*:- Dual Extruder 0.4 mm nozzle
c. *Material*:- PLA & ABS
d. *Speed*:- 100 mm/s to 300mm/s
e. *Bed size:*- 500 mm X 500 mm
f. *Bed temperature*:- Upto 70 o C
g. *Movement type*:- Satic Bed & Extruder Movement
h. *Make:*- SincGrid (Rachanakar 2.0) by taking (ABS) as the raw material. The process parameter and their values were (speed – 50 mm/s, Infield density – 100 percent, Forms of infill –hexagonal, extruder temperature-210 degree celcius and nozzle diameter-0.4 mm). The fabricated product was attached with bel and was then further analysed. Figure 4 shows the 3d printer setup and the fabrication process of the proposed belt.

(a) Fabrication of belt (b) Setup
Figure 4. 3D Printing process.

RESULT AND DISCUSSION

In present study various conditions assumed on the basis of the participant's survey and other formats, the FEA simulation was conduct to check the stress level faced by the students. The final von misses stress and principal stress were present in table 2.0 and the sample FEA visual result was shown in Figure 5.

Table 2. FEA simulation results at different boundary conditions for normal backpack.

Load Condition	Von Misses stress (MPa)	Principal stress (MPa)	Body part where max stress shown
Load 10 kg at both shoulder	2.84	4.23	Both Shoulder and Knee Joints
Load 5 kg at both shoulder	1.41	2.11	Both Shoulder and Knee Joints
Load 10 kg at walking condition	2.74	2.91	Both Shoulder and Knee Joints at single side
Load 5 kg at walking condition	1.23	1.29	Both Shoulder and Knee Joints at single side
Side Load 10 kg at both shoulder	2.84	4.24	Both Shoulder and Knee Joints
Side Load 5 kg at both shoulder	1.41	2.13	Both Shoulder and Knee Joints
Side Load 10 kg at walking condition	2.76	3.62	Both Shoulder and Knee Joints
Side Load 5 kg at walking condition	1.22	1.62	Single side of knee and shoulder

The Finite Element Analysis (FEA) simulations revealed varying levels of musculoskeletal stress under different load conditions and boundary scenarios for the normal backpack. At 10 kg load, stress peaks were observed at both shoulder and knee joints, while at 5 kg load, similar stress distribution was noted. Walking conditions induced asymmetrical stress distribution, particularly evident in single-sided shoulder and knee joints. These findings underscore the importance of considering load distribution and ergonomic design in backpack development to mitigate musculoskeletal stress among students.

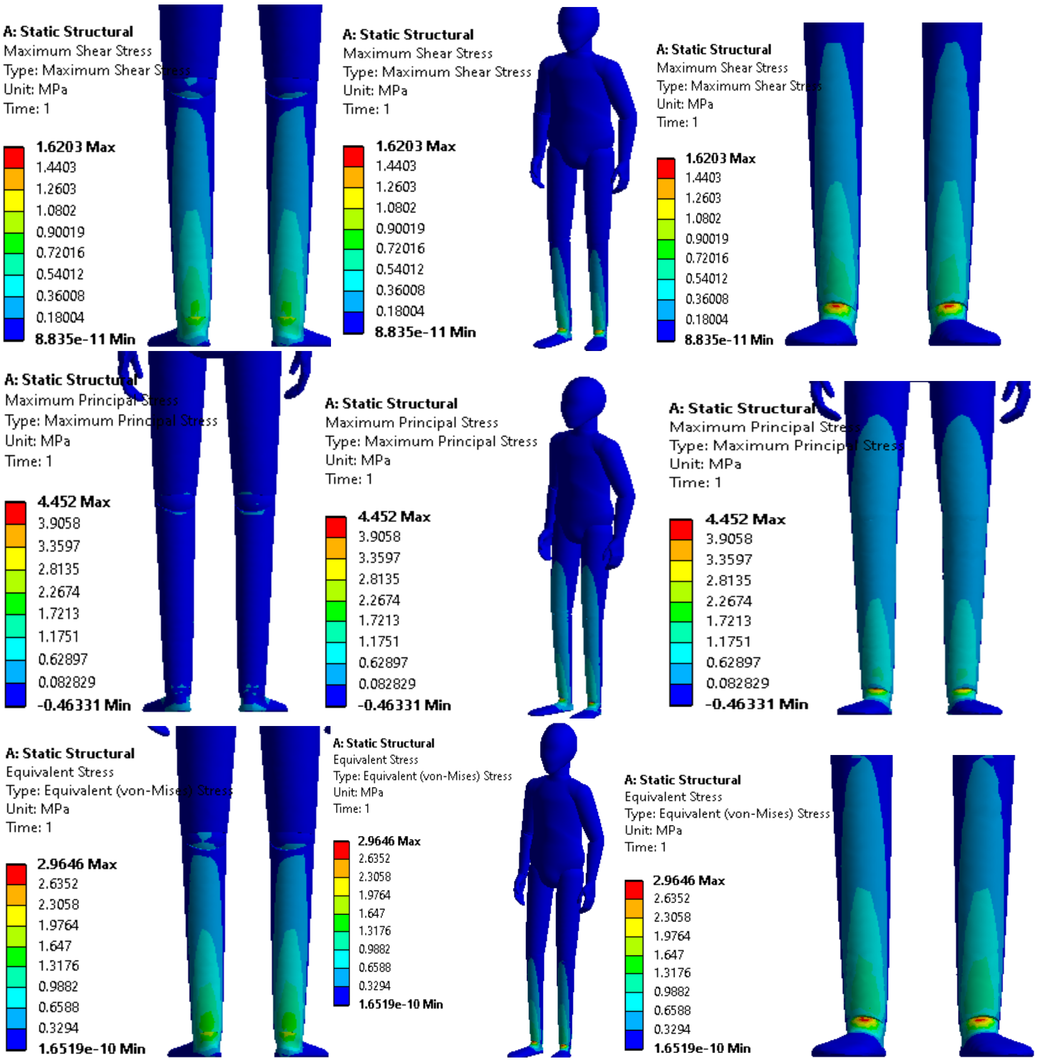

Figure 5. Distribution of principal stress on the shoulder and leg of student.

After the sucessful application of modelling and simmulation the fabrication of the belt on 3D printer was done for the sucessful appliction of the bag of the student. From the simmulation of the model it is observed that the stress was observed on the shoulder and on the leg portion of the student. For the load of th 5 kg on bag the stress of 1.50 MPa was observed on the shoulder and about 1 Mpa is observed o the lower part of the leg. It can be observed that due to the designe of belt the excessive load on the sholder has drastically reduced and the load is concentated at the lower part of back instead of sholder and similarly with the appropriate designe of the bag the stresses on the knee has been reduced significantlly pertaining to a sucessful designe approach.

Based on the modelling result, the fabrication of the belt was done using FDM method with ABS material using speed – 50 mm/s, Infield density – 100 percent, Forms of infill –hexagonal, extruder temperature-210 degree Celsius and nozzle diameter-0.4 mm as the process parameters value. These conclusions have lead to the discovery that the proposed belt has High rigidity with good insulation A Good impact strength, highly resistant to abrasion/strain and displays high dimensional stability It has also been found that it has a high surface brightness and an excellent surface aspect.

CONCLUSIONS

The research involving Finite Element Analysis (FEA) simulation leveraged detailed anthropometric data to model stress points and load distribution effectively. The boundary conditions were meticulously chosen, considering various daily scenarios ranging from carrying a backpack to walking and other physical activities. The simulation offered detailed insights into the points of high stress and guided the design of an optimized belt, aimed at distributing load more evenly across the body, thereby reducing the risk of musculoskeletal issues. The simulation modelling shows that the proposed belt possesses less stress on the children shoulder pertaining to a comfortable agronomics. Also the proposed ABS-polymer based belt produced by FDM is adequate in term of strength and patchable with the school bags of children.

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