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Redesign of computer workstation using ergonomics

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Abstract. Today's world is mostly occupied on computers, for which the workstation must be more comfortable to the operators. The objective of this paper is to develop a new design of a computer workstation (upright position) for preventing health risks associated with conventional workstations. The redesigned workstation incorporating ergonomics enhances the motivation, performance and productivity of the operator without affecting health. The vital requirements of computer workstation specified in various literature as per the standards for providing comfort to users is briefly presented. In addition, the product must be manufactured at less cost. To accomplish this design for manufacture and assembly (DFMA) principles are employed. Finally, the integrity of the redesigned workstation is analysed using simulation software.

1. Introduction

Now a days computers have become inseparable element of our lives. Right from homes to educational institutions, shops and industries, computers are used on personal and professional levels. It is practically impossible to find a place devoid of computers. It is the advent and advancement in the field of computer technology, led to widespread use of computers. Since computers have become are an essential component of our lives, so has computer workstations. The two basic parts of the workstation are: chair and desk. It is imperative to design the computer workstation such that it is comfortable for use, designed and manufactured at low cost. In this context, ergonomics and Design for Manufacture and Assembly (DFMA) is very pertinent. With increased use of computers, health and safety problems of operator increases. It is therefore, vital to incorporate ergonomic factors in the design of workstation. Ergonomics is the study of interaction between machines and people to improve the performance of systems by improving human-machine interactions [1]. Workstation design incorporating ergonomics, motivates the operator which leads to enhanced performance and efficiency. On the other hand, any uncomfortable body movements and body postures may affect the performance and health of the operator. The most commonly encountered health issues are, musculoskeletal disorder (MSD), headache, eye and mental fatigue, neck, shoulder and lower back problems. To facilitate the operator, proper lighting, temperature, adjustable keyboard and mouse supports, arm rests, foot rests etc. are provided in the workstation [2, 3].

Along with ergonomics, another aspect that needs to be considered in the design of workstation is DFMA. DFMA aims at simplifying the product in terms of design and manufacturing by minimizing the cost. In DFMA, design, manufacturing and assembly processes are analysed with a view to increase the design efficiency of the product without compromising its functionality. It is a blend of Design for Manufacture (DFA), a procedure of easing the manufacturing process and Design for Assembly (DFA), a process of easing the assembly operations to minimize the assembly time. The assembly efficiency is estimated in terms of DFA index, which is the ratio of assembly time of ideal design to assembly time of actual design. In order to make early cost estimates and trade off decisions, DFMA is usually implemented at the conceptual design stage. It can also be implemented for an existing product. Some of the advantages of implementing DFMA in product design are as follows: DFMA provides a systematic procedure for analysing products leading to reliable and less expensive products to manufacture and assemble. In addition, with reduction in the number of parts, leads to snowball effect on the cost reduction. It encourages the dialogue between manufacturing and design engineers, which means, the benefits of team work and concurrent engineering is achieved [4, 5].

In this work a conventional workstation is redesigned incorporating ergonomics and DFMA aspects. The consequences of incorporating these tools in the design of workstation are then presented. The workstation is designed using standard anthropometric dimensions. A three dimensional model is created in SOLIDWORKS software and then it is analysed for its structural stability using ANSYS simulation software.

2. Redesign of workstation using Ergonomics

The important requirements of workstation as specified by International Standards Organization (ISO) are the sitting posture, back rest, position of monitor, arm rest, leg room, work area which includes position of keyboard and mouse [6]. The conventional chair encourages a straight posture retaining right angles of elbow, hips, knees and ankles. Working in this kind of a posture for prolonged time leads to musculoskeletal disorders. Thus, the chair must be designed to permit reclined sitting posture [7]. The seat height and depth of chair must be adjustable permitting the feet to rest on the footrest and accommodate wide range of people from lowest to uppermost setting [6]. The back rest should provide ample support and clearance for buttocks. The inclination and height of back rest must be adjustable so that one can sit in wide range of postures [8]. The arm rests which supports the elbow while using keyboard and mouse is most preferable, as it reduces the load on the arms, shoulder and neck. In fact, it is desirable to design arm rests as an optional feature. The height, length and width of the arm rest must be such that it provides sufficient cushioning to reduce pressure on elbows and underside of the forearms [9]. The monitor position, viewing distance and viewing angle are other vital parameters. The height to which monitor positioned must be such that it does not result in greater muscle activity. If it is positioned too low, it increases the flexion of the head relative to neck. The range of preferable viewing distance is 63 – 85 cm for people with normal visual capabilities. Beyond this range, it leads to visual fatigue. The monitor display must be positioned such that viewing area must be with 0^o – 60^o [10, 11]. In addition, the work surface height, must be adjustable; the leg room must be ample; the surface area containing keyboard and mouse must be sufficient and adjustable [12].

The recommendations mentioned above are incorporated in the redesigned workstation. The conventional and redesigned workstations are shown in figure 1 and figure 2. The chair and desk of conventional workstation is integrated in to a single entity in the redesigned one. The computer monitor can be fitted to the monitor holding arm. The back rest, arm rest, leg support, foot rest, monitor holding arm (facilitates the adjustment of viewing distance, viewing height and angle), keyboard and mouse supports are all adjustable. The whole unit can be transferred easily. For designing a standard workstation it is necessary to use anthropometric measurements [13, 14]. In this work, the workstation is designed for students whose anthropometric dimensions are shown in figure 3 and table 1.


(a)

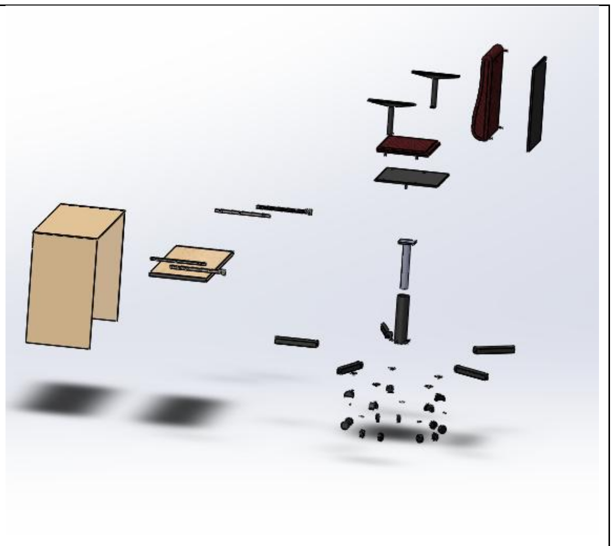
(b)

Figure 1. Conventional workstation (a) Assembled view (b) Exploded view


(a)


(b)

Figure 2. Redesign workstation (a) Assembled view (b) Exploded view

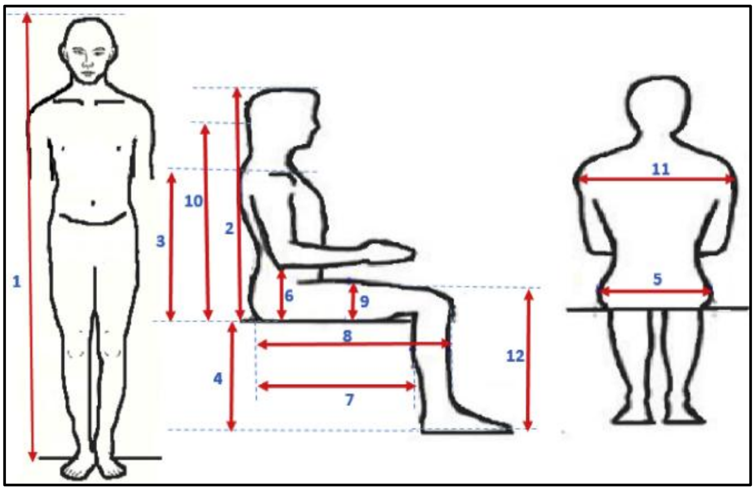

Figure 3. Anthropometric data: stature (body height) (1), sitting height (erect) (2), shoulder height, sitting (3), lower leg length (popliteal height) (4), hip breadth, sitting (5), elbow height, sitting (6), buttock-popliteal length (seat depth) (7), buttock-knee length (8), thigh clearance (9), Eye height, sitting (10), shoulder (bideltoid) breadth (11), knee height (12), and body mass (weight) (13) [13]

Table 1. Anthropometric dimensions used in redesigning ofworkstation [13]

Criteria	Description	5^{th} Female percentile, mm	95^{th} Male percentile, mm	Average (mm)
Stature	Body Height	1465	1810	**1637.5**
Sitting height	Erect	730	880	**805**
Shoulder Height	Sitting	500	569	**534.5**
Lower Leg Length	Popliteal Height	375	487	**431**
Hip Breadth	Sitting	320	**380**	350
Elbow height	Sitting	155	**245**	200
Buttock–popliteal length	Seat depth	390	520	**455**
Buttock–knee length	-	505	**610**	557.5
Thigh clearance	-	100	**185**	142.5
Eye height	Sitting	630	780	**705**
Shoulder breadth	-	350	**462**	406
Knee Height	-	420	570	**495**
Body mass	Weight **(kg)**	40 kg	**91.5 kg**	65.75 kg

The dimensions of the workstation is chosen in the range of 5^{th} percentile of the size of female to the 95^{th} percentile of the size of male (which are lowest and upper most dimensions). For a few criteria, average dimensions are chosen while for the rest maximum dimensions are used which allows more comfort for the user. The bold faced dimensions in Table 1 are employed in designing the workstation. To verify its structural integrity, the model was analysed by subjecting to a load of 91.5 kg. The analysis is performed in ANSYS simulation software. The induced stresses and deformations are shown in figure 4 and figure 5 respectively. It can be noticed that, the maximum stress is well below the tensile strength of 550 MPa. From these results, it is inferred that the redesigned model is structurally stable.

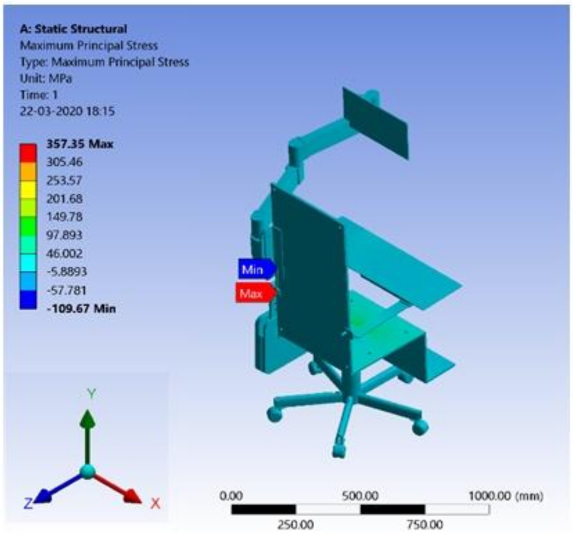

Figure 4.von-Mises stress distribution

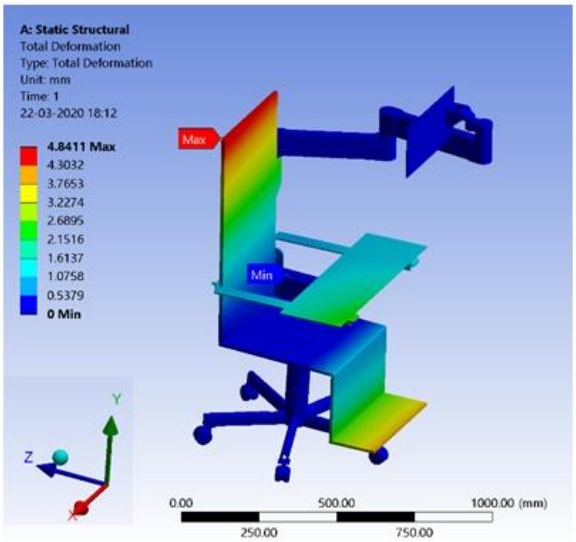

Figure 5. Deformation distribution

3. Analysis of workstation using DFMA

The components of the conventional workstation are, a chair and a desk. The constituent parts of the conventional workstation, number of items, materials and manufacturing method employed and price of each part is listed in table 2. The total number of parts are 33 and the total cost of workstation is ₹ 26,696.97. Similarly, in table 3, the details of the redesigned workstation are given. In the redesigned one, the total number of parts are 34 while the total cost is ₹20,884.82. The number of parts in redesigned workstation is one excess relative to the conventional one. This is due to the mechanisms involved in redesigned workstation, the number parts could not be minimized. However, the total cost is decreased by 21.77%, which is a significant reduction.

Table 2. Workstation details of conventional design (before implementing DFMA)

Part	Material	No. of item	Manufacturing method	Total cost (₹)
Computer table	Wood	2	Machining	**9347.18**
Keyboard tray	Wood	4	Machining	**3019.06**
Drawer rail	Grey cast iron	2	Roll forming machines	**118.94**
Cabinet rail	Grey cast iron	2	Roll forming machines	**219.1**
CPU side drawer	Wood	1	Machining	**2535.33**
Chair main body	Structural steel	1	Forging	**2644.66**
Chair leg	ABS plastics	5	Injection moulding	**517.34**
cushion	Polyurethane foam	1	upholstery	**461.07**
Hand rest	ABS	2	Injection moulding	**793.78**
Castor wheel	ABS	9	Injection moulding	**1812.33**
Hand rest support	Stainless steel	2	Machining	**1193.78**
Main cylinder cover	Stainless steel	1	Machining	**1165.98**
Main cylinder piston	Structural steel	1	Casting and Forging	**1766.29**
TOTAL		**33**		**26696.97**

Table 3. Redesigned workstation details (after implementing DFMA)

Part	Material	No. of item	Manufacturing method	Total cost (₹)
Hand lever	ABS plastics	1	Injection moulding	**258.28**
Gear	Grey cast iron	1	Machining	**564.3**
Box base	ABS plastics	1	Injection moulding	**586.09**
Springs	Steel	2	Purchased	**343.7**
Monitor holder arm	ABS plastics	2	Injection moulding	**308.54**
Arm pipe	Galvanized steel	2	Purchased	**1037.32**
Arm mount	ABS plastics	4	Injection moulding	**1591.16**
Pivot base	ABS plastics	1	Injection moulding	**237.14**
Monitor tray holder	ABS plastics	3	Injection moulding	**1671.45**
Monitor tray	Structural steel		Machining	**557.15**
Keyboard holder	Structural steel	1	Machining	**1963.58**
Leg rest	Structural steel	1	Machining	**1529.25**
Hand rest	Aluminum alloy	4	Machining	**1293.78**
Chair main body	Structural steel	1	Machining	**3309.36**
Cushion	Polyurethane foam flexible	2	Upholstery	**1694.6**
Main cylinder piston	Structural steel	1	Machining	**1766.29**
Main cylinder cover	Stainless steel	1	Machining	**1165.98**
Castor wheel	ABS plastics	5	Injection moulding	**1006.85**
TOTAL		**34**		**20884.82**

4. Conclusions

In this work, the implementation of ergonomics and DFMA is exemplified using the redesign of workstation. The following observations are made from this work:

(a) The redesigned model is more comfortable, easily portable and less expensive. As a consequence, the performance of the operator improves without affecting health.
(b) Implementing DFMA has significantly reduced the cost i.e., by 21.77%. The analysis results revealed that the redesigned one is structurally stable.

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