Lecture Notes in Mechanical Engineering

A. Arockiarajan · M. Duraiselvam ·
Ramesh Raju · N. Subba Reddy ·
K. Satyanarayana *Editors*

Recent Advances in Materials Processing and Characterization

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Contents

Productivity and Safety Improvement in Industry Using Ergonomics—A Case Study 1
Hanumantu Krishna Murty Dora, L. Siva Rama Krishna, and P. Ravinder Reddy

Transmetalation: A Post-synthetic Modification Tool for Functional Metal–Organic Framework Materials 15
Sathish Kumar Kurapati

The 2D and 3D Protein Sequencing Implementation Using Ant Colony Optimization Algorithm 33
B. Ramya Sree, T. Indira Priyadarshini, and Tejaswi Borra

Optimizing the Peak-Ageing Conditions for Microalloyed 2219Al Alloys 43
Sanjib Banerjee and Sanjib Gogoi

Optimization of Process Parameters in W-EDM with HCHCR by Using Taguchi Optimization Technique and Grey Relational Analysis 55
M. Sathish Kumar and B. Satyanarayana

Future Generation Materials and Techniques for Sustainable Construction 67
Rajesh Kumar, Vanita Aggarwal, and Surinder M. Gupta

Tribological Characterization of Microalloyed Al-Cu Alloys by Artificial Neural Network Modeling 83
Sanjib Gogoi, Dewesh Kumar, Sanjib Banerjee, Sushen Kirtania, and Satadru Kashyap

Design and Fabrication of Impression Creep Testing Setup and Experimental Validation with 2219Al Alloys 93
Sanjib Gogoi, Reeturaj Boruah, Mehsana Ahmed, Sanjib Banerjee, Sushen Kirtania, and Satadru Kashyap

Theoretical Comparison of Properties and Their Characteristics Features for Additive Manufactured Metal and Ceramic Structures 107
Utkarshika Chandra, Rajesh Kumar Porwal, Sanjay Mishra, and Basanta Kr Bhuyan

Relative Investigation of Thermal Buckling Analysis of Nickel and Functionally Graded Material Rectangular Plate 127
Mrinal Gautam and Manish Chaturvedi

Aqueous Extract of *Colocasia Esculenta* Leaves for Prevention of Low Carbon Steel Corrosion in 0.5 M NaCl 137
Vinit Kumar Jha, Vivek Porwal, Gopal Ji, and Rajiv Prakash

Alternate Material's Approach Toward Green Construction 149
Nitu, Rajesh Kumar, Vanita Aggarwal, and Surinder M. Gupta

Effect of Various Tools on Bone Condensing to Improve the Stability of Dental Implant 163
Mohit Phadtare, Parth Jain, and Pankaj Dhatrak

Investigation on the Microstructure–Corrosion Correlation of Commercially Available AISI 1020 and 304 Steel 175
Sudesna Roy, Bijaya Bijeta Nayak, and Sasmita Sahu

Thermal Buckling Analysis of Tri-directional Functionally Graded Material Plate 183
Mrinal Gautam and Manish Chaturvedi

Investigation of Modal Analysis of Tri-Directional Functionally Graded Material Plate 191
Mrinal Gautam and Manish Chaturvedi

Modelling of Structural Responses for Pineapple Leaf Fibre Epoxy Composite 199
Partha Pratim Borah, Satadru Kashyap, Sushen Kirtania, and Sanjib Banerjee

Investigation of Mechanical Properties of Carbon Fiber/Graphene Nanoplatelet/Epoxy Hybrid Nanocomposites 211
Mriganan Madhab Bordoloi, Sushen Kirtania, Satadru Kashyap, and Sanjib Banerjee

Finite Element Analysis of Natural Hemp Fiber-Based Composite for Semi-elliptical Multi-leaf Spring 225
Bitu Moni Das, Sushen Kirtania, Sanjib Banerjee, and Satadru Kashyap

Fabrication and Testing on Mechanical and Thermal Properties of Jute/Hemp Fiber Hybrid Composites 239
K. Venkatarao, K. SivajiBabu, and G. Ranga Janardhana

A Review: Investigation of Length Effect in Carbon Nanotube (CNT)-Reinforced Aluminum (Al) Composites 253
K. G. Thirugnanasambantham, Devarapalli Sai Charan Reddy, Tadikonda Vishnu Vardhan, and Sama Abhinav Reddy

Experimental Investigation on the Performance of Inconel 718 Using MQL Grinding Operation 263
Farooqui Rizwan Ahmed, Prameet Vats, Rabesh Kumar Singh, and Anuj Kumar Sharma

Investigating Machinability of Microalloyed Al-Cu Alloys by Simulation of Cutting Force 275
Sanjib Gogoi, Bhargab Nath, Bhagyashree Konwar, Avinava Bora, Sanjib Banerjee, Satadru Kashyap, and Sushen Kirtania

Electrochemical Analysis of Corrosion Inhibition of Low Carbon Steel in 0. 1 N HCl by Bottle Gourd Peels 287
Pragati Srivastava, Shweta Pal, Vinit Kumar Jha, Gopal Ji, and Rajiv Prakash

Study of Rotating Arc Welding Process for Joining of Pipes: An In-Depth Review 297
Ahmed Abdul Muneem, P. Laxminarayana, and M. Viquar Mohiuddin

A Study of the Coefficient of Friction in DP-590 Steel Sheets Forming 311
K. Seshacharyulu and B. Balu Naik

Enhancement of Machinability Characteristics of Superalloys Using Textured Tools: A Review 319
Krishna Mohan Buddaraju, G. Ravi Kiran Sastry, Satyanarayana Kosaraju, and G. Sainath

Identification of SMAW Surface Weld Defects Using Machine Learning 339
K. Ramesh, E. V. Ramana, L. Srikanth, C. Sri Harsha, and N. Kiran Kumar

The Influence of Machine Learning in Additive Manufacturing 351
Ramesh Raju, N. Manikandan, D. Palanisamy, P. Thejasree, P. Satheesh Kumar, P. Mohammed Rizwan Ali, and P. Sivakumar

Temperature Robust Health Bench-Marking and Monitoring of an Heritage Suspension Bridge Using Coupled IWCM and TBSI Method 363
Yeturi Pramod Kumar Reddy and Subhamoy Sen

Electrical Characterization of Silicon Nitrate-Coated Polycrystalline Solar Cell 371
Srinivasa Rao Davu, Ramesh Tejavathu, and Suresh Kumar Tummala

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Productivity and Safety Improvement in Industry Using Ergonomics—A Case Study

Hanumantu Krishna Murty Dora, L. Siva Rama Krishna, and P. Ravinder Reddy

Abstract The goal of fitting task is popularly known to be ergonomics. Enthusiastic superior ergonomics attains improved productivity thereby improving the health and safety of employees, privileged job contentment and better conformity by means of government set of laws. The broad spectrum of ergonomics ideology with the intention of functional to the place of work embraces aiming for energetic in opposition to static work, keeps away from overload of muscles, to make effective use of work surface heights, avoid deviant postures and educate individuals to utilize workplace, ability and apparatus appropriately. This present work aims to determine the productivity rate of the industry and product produced by the company before and after the intervention of the ergonomic principles to the employees of organization working in various departments. Parameters considered as ergonomics are anthropometry, seat design, manual materials handling, and it focuses on most common musculoskeletal disorders (MSDs) such as cumulative trauma disorders and lower back injuries.

Keywords Musculoskeletal disorders (MSDs) · Cumulative trauma disorders (CTDs) · Ergonomics · Productivity · Stress

1 Introduction

Ergonomics is the sciences of fitting task and design the office, by observance in intellect potentials and boundaries of the worker. Poor work-site intention leads to exhaust, frustrated and hurt workers. This infrequently led to the majority prolific

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workers. More liable, it escorts to an aching and expensive injury, inferior productivity and underprivileged product worth. Methodical ergonomics upgrading progressions remove threat factors that escort to musculoskeletal injuries and tolerates for enhanced human presentation and efficiency. By creation enhancement to the work route, one can eliminate barriers to greatest safe work routine. The company is laid with socio-responsibility to see that the worker is surrounded by their body's abilities and boundaries. Through well, an ergonomics enhancement method can be an entire provider to ones company's competitiveness in the market and present a better work familiarity for the worker community. Main principle behind the ergonomics is to trim down work stresses that may affect the health consequence and can be stop happening [1]. These work stress hormonal (e.g. extreme replication, vigorous exertion, static positions, vibrations, cold temperature, compression, poor work-station design and awkward movements) support rhythmic or growing injuries and accordingly exaggerate the commonness of common musculoskeletal turmoil like tendonitis, bursitis, epicondylitis, carpal tunnel syndrome, trigger finger, etc. [2]. In accumulation, nonexistence of ergonomically premeditated job has resulted in corporal vulnerability (e.g. light, temperature, vibration, noise and radiations) chemical or biological vulnerability; psychosocial vulnerability; sickness non-attendance; industrial cancers; and accidents [2–4].

2 Literature Review

In current scenario, it has been seen a substantial increase of cumulative trauma disorders (CTD) in past decades. In the USA, the digit of statement upper-limit confusions has tripled stuck between 1986 and 1993 by [5]. A comparable inclination is noticed in supplementary mechanized nations. Hagberg et al. [6] designated "Work-related musculo-skeletal disorders (MSD) represent a chief difficulty in countless mechanized countries." Cumulative trauma disorders (CTDs) accounted in the USA for above 60% of all job-related sickness in 1990 [7]. Fraction of this augment is ascribed to enhanced appreciation and treatment [8]. Also, of significant consequence, is the detail that vocations in a traumatic and exceedingly aggressive global economy tend to be exceedingly rapidity and repetitious [9–11].

Design is capable of trim down the possibility changes and corollary of error [12]. Emergent a structure ample of accepting the users, the paraphernalia to facilitate they utilize and the atmosphere in which the employment survive and are wired to drawn near. [13]. Designed for medical diplomacy, such as concoction pumps, here are numerous cases in spot of revamp that would diminish fault rates [14, 15]. In this gear priceless breaks have been missed: formerly apparatus has been positioned; it is not easy to keep informed or amend it. There comprise been titled for an increase of rate of the amalgamation of Human Factors (HF) and ergonomics in unwearied protection, together with the conception of "market armed forces for producers to generate safer goods that integrate Human Factor Engineering [HFE] principles and performance" [16]. The term HFE is not only applicable to application of theory, but also statistics and scheme to propose in classify to optimize human security and largely scheme concert. Modern study tentative to the rapport between healthcare proficient and apparatus contributor has brought into being numerous hurdles to the development of common argument. Money et al. [17] initiate that UE/HFE observed is inhibited by an excess of confidence on partial information of elder healthcare staff. They also originate an escaping of session in the midst of patients or fewer senior staff, and a propensity to craft design alterations on the root of perception somewhat than the more formal approach of user testing. There were biases towards collecting measures of worth to convene the wants of acquiring or valuation agencies [18]. To regulate lessen the encumber of the industrial vulnerability, especially in the health concern sector, here is a necessitate to intents and purposes pay attention to wellbeing of all the stakeholders [19]. On other hand, it is a responsibility to rationalize the complete progression of health care to guarantee facilitation of ergonomically promoter observers [4]. The planned quantify series guarantee the proper outline of the company; creating consciousness between the hospital staff in relation to the livelihood vulnerability and necessitate by means of individual defensive equipment/subsequent the homogeneous code of behaviour; implementing proper procedures to preserve hygiene surrounded by the property and therefore be in command of infectious diseases; mounting a protocol for mannering a medical assessment of the healthcare employees, particularly nursing and maintenance staff, to consent untimely gratitude of signs and indications of occupation-induced sickness; and by approving appropriate engineering events to make possible computerization, diminish human workload and concurrently make certain patient safety [3, 4, 20–22].

Little research work was done on ergonomic factors that affect the productivity rate in the industry. The present work is focused on studying the ergonomic factors affecting the productivity rate in (XYZ) PVT LTD Company. (As per requirement company name not to be mentioned).

3 Productivity and Case Study

Productivity can also be determined as the efficiency of the production of the product in the company. It is expressed as ratio of output achieved to the input given in the production process. It is a key parameter in industries and also a performance factor to firm and nation. Living standard is based on the productivity of the goods and services and many more in the nation. It also helps in profitable business to the entrepreneurs. During the productivity, it may incur the risk factors in terms of ergonomics risk like musculoskeletal disorders (MSDs) such as cumulative trauma disorders and lower back injuries and also high task repetition, forceful exertions and repetitive sustained awkward postures.

A. ***Company Profile:***

It is multibranded company which produces variety ranges of chemicals, unsaturated polyester resins and specialty chemicals. It is located 20 km from Hyderabad.

B. ***Parameters used in evaluating the performance of the employees in organization.***

Musculoskeletal disorder (MSD) is a disorder which affects the human body movement (i.e. ligaments, discs, blood vessels, tendons and muscles). Apart from this, there are many effects that causes due to MSDs are radial tunnel syndromes, ruptured disc, tension neck syndrome, etc. Cumulative trauma disorder (CTD) is one of the MSDs which cause repetitive strain injuries (RSIs). These injuries mainly occur in joints, moving parts, low back, shoulder, wrist, knee and elbow.

The stresses developed in the body parts are assessed based on the age groups, departments, shift system, and the report is submitted to the organization to study the effect of the productivity rate. Sample questionnaires as shown in Figs. 1, 2, 3, 4 and 5 are used for evaluating the process. Number of employees in organization are approximately 200 with 25–40 members in each department including supervisors and labours.

In the form, the stresses developed in body parts like hand and wrist, back, neck and knee are determined by following the rating system from 0 to 10. Zero is no

Stresses on Body Parts March(2017)

Name: shanthan Krishna
Age: 38
Department: Storage
Shift Time: Morning

No:	Body Parts(stress)	Rating (0-10)
1.	Hand & Wrist	5
2.	Back	6
3.	Neck	7
4.	Knee	5

Questions	Yes	No
1) Did the company taught you safety instructions ?	✓	
2) Did worker safety behavior change after safety training ?	✓	
3) Did the case study help you people ?	✓	

Comments:

Fig. 1 Assessment sheet used in studying the behaviour of the employee of the organization in storage department morning shift

Stresses on Body Parts February(2017)

Name: Prasad Rao
Age: 39
Department: PLANT D
Shift Time: EVENING

No:	Body Parts(stress)	Rating (0-10)
1.	Hand & Wrist	7
2.	Back	7
3.	Neck	7
4.	Knee	6

Questions	Yes	No
1) Did the company taught you safety instructions ?	✓	
2) Did worker safety behavior change after safety training ?		✓

Fig. 2 Assessment sheet used in studying the behaviour of the employee of the organization in plant D evening shift

Stresses on Body Parts March(2017)

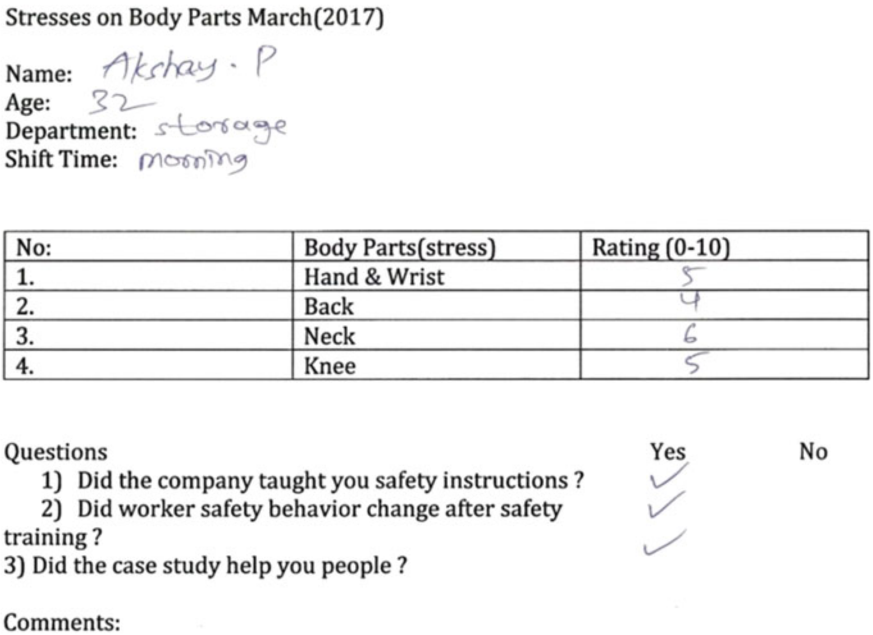
Name: Ram Murthy
Age: 36
Department: GOODS LOADING
Shift Time: MORNING.

No:	Body Parts(stress)	Rating (0-10)
1.	Hand & Wrist	6
2.	Back	6
3.	Neck	7
4.	Knee	6

Questions	Yes	No
1) Did the company taught you safety instructions ?	✓	
2) Did worker safety behavior change after safety training ?	✓	
3) Did the case study help you people ?	✓	

Comments:

Fig. 3 Assessment sheet used in studying the behaviour of the employee of the organization in goods loading morning shift



Stresses on Body Parts March(2017)

Name: Akshay . P
Age: 32
Department: storage
Shift Time: morning

No:	Body Parts(stress)	Rating (0-10)
1.	Hand & Wrist	5
2.	Back	4
3.	Neck	6
4.	Knee	5

Questions	Yes	No
1) Did the company taught you safety instructions ?	✓	
2) Did worker safety behavior change after safety training ?	✓	
3) Did the case study help you people ?	✓	

Comments:

Fig. 4 Assessment sheet used in studying the behaviour of the employee of the organization in storage department morning shift

(a) (b)

Fig. 5 **a** Dispatch section and **b** loading and unloading of the materials

Table 1 Assessment in storage department (February)

Employees assessed	Body parts (stress)	Average rating (0–10) before ergonomics intervention (1st Feb)	Average rating (0–10) after ergonomics intervention (28th Feb)	Percentage of change in stress behaviour
30	Hand and wrist	8	4	50
30	Back	7	4	42.8
30	Neck	8	4	50
30	Knee	6	3	50

effect, and 10 is maximum effect. Based on this rating system, the performance is evaluated in various plant locations in the organization. The ratings of the employees are shown in Tables 1, 2, 3, 4, 5 and 6.

Table 2 Assessment in plant D department (February)

Employees assessed	Body parts (stress)	Average rating (0–10) before ergonomics intervention (1st Feb)	Average rating (0–10) after ergonomics intervention (28th Feb)	Percentage of change in stress behaviour
35	Hand and Wrist	7	3	57.14
35	Back	7	3	57.14
35	Neck	8	4	50
35	Knee	7	3	57.14

Table 3 Assessment in packing department (February)

Employees assessed	Body parts (stress)	Average rating (0–10) before ergonomics intervention (1st Feb)	Average rating (0–10) after ergonomics intervention (28th Feb)	Percentage of change in stress behaviour
32	Hand and wrist	8	4	50
32	Back	7	3	57.14
32	Neck	6	4	33.33
32	Knee	7	3	57.14

Table 4 Assessment in dispatch department (February)

Employees assessed	Body parts (stress)	Average rating (0–10) before ergonomics intervention (1st Feb)	Average rating (0–10) after ergonomics intervention (28th Feb)	Percentage of change in stress behaviour
40	Hand and Wrist	9	4	55.55
40	Back	8	4	50
40	Neck	7	3	57.14
40	Knee	8	3	62.5

Table 5 Assessment in administrative office (February)

Employees assessed	Body parts (stress)	Average rating (0–10) before ergonomics intervention (1st Feb)	Average rating (0–10) after ergonomics intervention (28th Feb)	Percentage of change in stress behaviour
20	Hand and wrist	10	4	60
20	Back	8	5	37.5
20	Neck	9	4	55.55
20	Knee	7	3	57.14

Table 6 Productivity

Department	Employees	Productivity before ergonomic intervention (January)	Productivity after ergonomic intervention (February)	Percentage of change in stress behaviour
Storage	30	111	127	12.59
Plant D	35	97	116	16.37
Packing	32	130	153	15.03
Dispatch	40	130	159	18.23
Administrative office	20	20	30	33.33

4 Results and Discussions

The productivity rate of the company is based on the output that they achieved at the end of the month. In this process, ergonomics principle was used to predict the productivity rate and safety of the employees of the organization. Beginning of the month a report as shown in Fig. 1 is submitted to the employees to rate the stresses that they are undergoing during their various operations in the organization in various departments. Stresses developed in the body are rated from the scale of 0–10, and the same data is collected by each employees working in the department without ergonomic intervention and with ergonomic intervention. The results are plotted in the graphs from Figs. 6, 7, 8, 9, 10, 11 and 12.

From the results, it is observed by following the ergonomic intervention in the company in various departments the health issues in terms of stresses developed

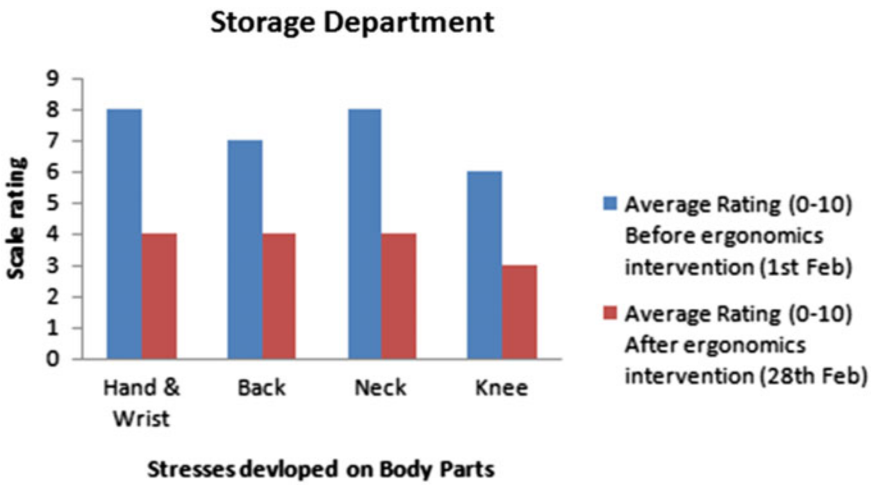


Fig. 6 Stress developed on the body part before and after ergonomic intervention in storage department

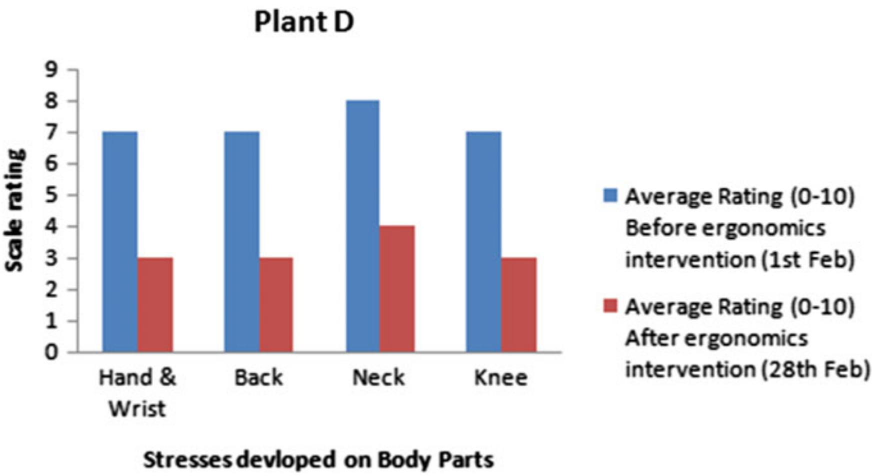


Fig. 7 Stress developed on the body part before and after ergonomic intervention in plant D department

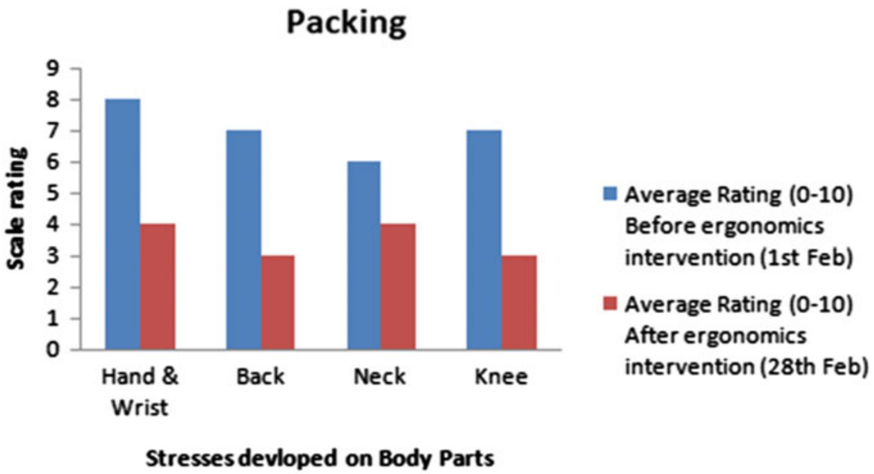


Fig. 8 Stress developed on the body part before and after ergonomic intervention in packing department

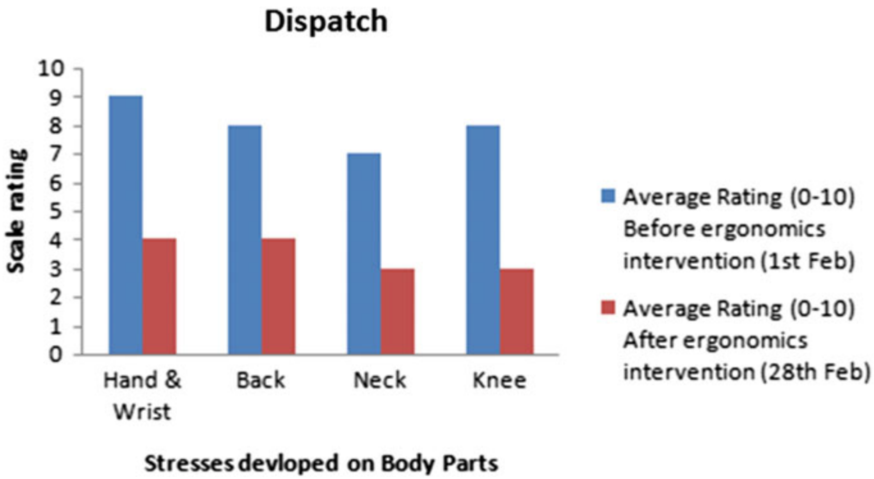


Fig. 9 Stress developed on the body part before and after ergonomic intervention in dispatch department

in the body parts have reduced to some extent through which the productivity rate has increased. This increase in productivity rate is because the employees have not availed the medical leaves and they are continuously working in their respectively department.

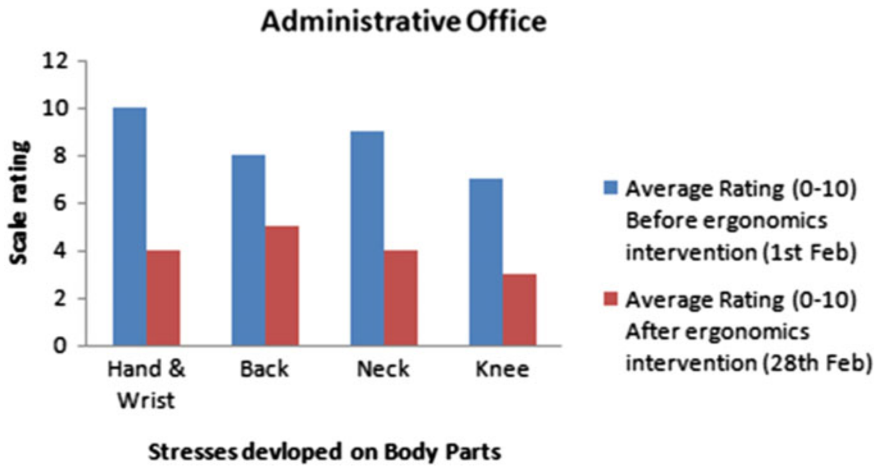


Fig. 10 Stress developed on the body part before and after ergonomic intervention in administrative office

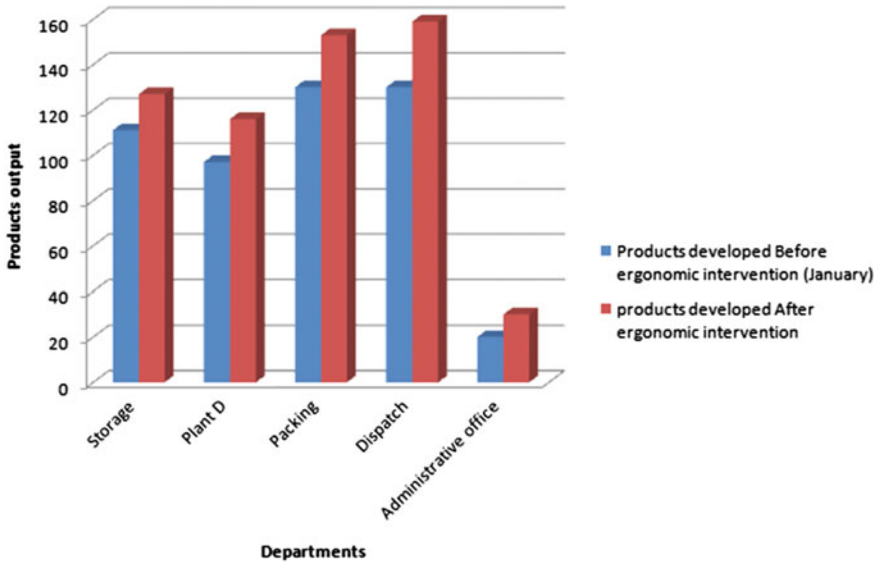


Fig. 11 Product developed or output achieved by the company before and after ergonomic intervention for February month

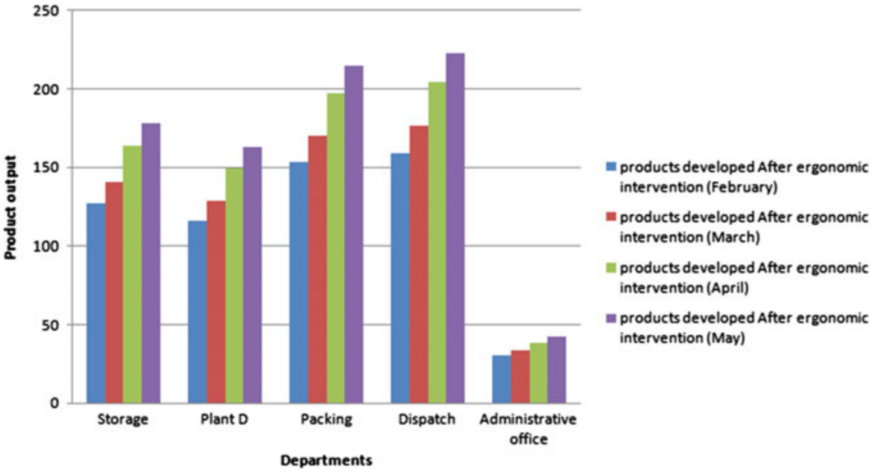


Fig. 12 Product developed or output achieved by the company after ergonomic intervention for February to May months

5 Conclusion

An ergonomic intervention was performed in which those relevant anthropometric dimensions involved in man–machine interaction were identified. These improvements to the ergonomics of the workplace increased the productivity and reduced the risk to health issues and accidents. The application of ergonomic principles would help to increase workers performance, productivity and safety. Also it helps human operator to be comfortable and secure. Since at present time, the vast majority of the companies acquired Advanced Manufacturing Technology in order to be competitive, ergonomic and safety aspects must be considered as one of most effective ways to accomplish the improvement in productivity and safety.

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Transmetalation: A Post-synthetic Modification Tool for Functional Metal–Organic Framework Materials

Sathish Kumar Kurapati

Abstract Post-synthetic modification is a valuable approach to tune the properties of materials after the traditional synthetic protocols without disturbing the core structure. Several post-synthetic methods are adopted for the modification of Metal–Organic Frameworks (MOFs). Transmetalation is a post-synthetic method where new metal ions exchange the metal ions of parent MOFs to tune the chemical and physical properties. Several transmetalation approaches were employed for the complete exchange or partial exchange of parent metal centers to give MOF materials with enhanced properties. In this article, a brief idea about transmetalation and its potential in the making functional MOFs was discussed by listing a few examples of contemporary interest.

Keywords Metal–Organic Frameworks · Post-synthetic modification · Transmetalation · Single-crystal to single-crystal transformation · Mixed metal MOFs

1 Introduction

Metal–Organic Frameworks (MOFs) secured their place as essential function materials of the decade for their miscellaneous applications in catalysis [1, 2], gas storage [3], gas separation [4–8], sensors [9, 10], drug delivery [11], and solar energy-harvesting [12]. Properties of MOFs such as surface area [13], void space [14], luminescence [15], magnetism [16], and thermal and mechanical stability [17, 18] are remarkable. These versatile properties of MOFs are made them as functional materials in a diverse range of applications. The structural symphony of 2D and 3D MOFs is an example of masterpiece artwork and provides cavities and channels [19–21]. "Node and spacer" [22, 23] and "secondary building unit (SBU)" [24, 25] models are generally adopted to design and synthesize crystalline MOFs. A broad synthetic

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protocol for MOFs generally involves adding one or more organic ligand spacers to the metal precursor solution. The reaction mixture is allowed to react under various solvothermal conditions to obtain desired crystalline MOF material. The traditional way to modify the chemical and physical properties of MOFs involves a pre-synthetic modification of organic ligands and the usage of such modified ligands in the preparation of MOFs with expected properties. However, such pre-synthetic modifications may yield a MOF with different topology and undesired properties [26, 27]. On the other hand, the new functional groups of ligands may involve coordination with the metal ion, which is essential to be in its free form to impart the desired chemical and physical properties to the MOF. Sometimes, the desired functional group may not survive the reaction conditions and may undergo functional group transformation [28]. The post-synthetic modification (PSM) of MOFs is an important tool for chemists to synthesize desired MOFs without disturbing the existing network structure. The feasibility of PSM methods is mainly influenced by the stability of metal–ligand bonds in MOFs and the porous nature of MOFs to allow the exchange of guest species [29, 30]. The PSM methods for MOFs are majorly four types: (1) Metal-based, (2) Ligand-based, (3) Guest-based, and (4) Metal and Ligand-based (Fig. 1). The inclusion or replacement, or removal of metal nodes, ligands, guest species, and all together are involved in the PSM of MOFs. However, in the case of ligand-based modifications, the alteration of functional groups is also very often [31]. In general, these PSMs do not alter the topology of original MOFs, and, majorly, the reaction process is a single-crystal to single-crystal (SCSC) transformation [32]. Overall the PSM of MOFs offers the inclusion of a diverse range of functional groups on identical topologies with significant control over the functional groups and degree of modifications. Easy purification procedures are an added advantage since the PSMs involve heterogeneous reactions. Hence, tuning of MOFs' chemical and physical properties is more facile via a PSM method.

PSM is also found in other materials like proteins, carbon nanotubes (CNTs), and porous zeolites and silicates. The modification of proteins after translation is known as a post-translation modification (PTM). This concept observed in nature is very similar to PSM, where proteins are covalently modified for functionalization, and the modifications generally occur on amino acid sidechains of polypeptides [33, 34].

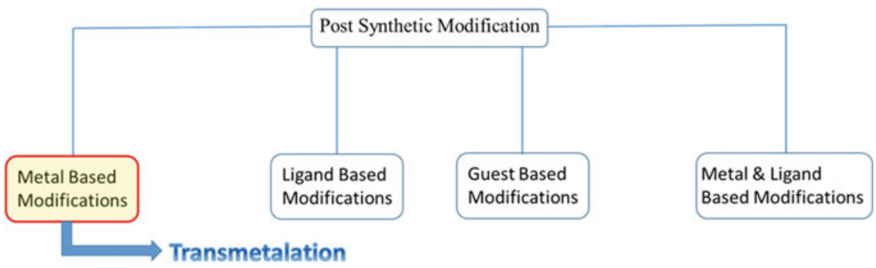


Fig. 1 Classification of post-synthetic modifications of MOFs

The artificial PTM approach is widely applied to elucidate the function and mechanism of proteins and protein-bound pharmaceuticals in living organisms [35, 36]. PSM approaches extensive studies for carbon nanotubes (CNTs) for functionalization. CNT is a bulky π-conjugated alkene. Hence, the addition reactions (nucleophilic addition, radical addition, cycloaddition, and halogenation) and coordination of transition metal ions are used to modify the CNTs chemically. Such chemically modified CNTs found exciting applications like differentiation of single-walled CNTs with metallic and semi-metallic conductivities [37], chemical and biochemical sensing [38], materials applications [39, 40], and drug discovery and delivery [41, 42].

The replacement of coordinated water ligands with pyridine ligands in HKUST-1 is probably the first reported example for PSM of MOFs. The exchange of aqua ligands with pyridine ligands is facilitated by huge 9×9 Å^2 square channels [43]. Another significant advancement in the PSM of MOF is the inclusion of ethylenediamine to coordinatively unsaturated Cr(III) metal nodes in MIL-1 MOF. Further, the amines of ethylenediamine groups are protonated to encapsulate the nanoparticles of noble metals like Pt and Pd. These modified MOFs are found to be excellent catalysts in Heck coupling reactions [44]. Coordinatively unsaturated metal centers of a copper-based MOF constructed with 1,3,5-tris(1H-1,2,3-triazol-5-yl)benzene) (H_3BTTri) linkers are functionalized with ethylenediamine via a PSM synthetic protocol. The derived MOF, which shows excellent gas absorption ability toward CO_2 over N_2, is also a considerable advancement in the PSM of MOF at the early stages [45]. These examples have provoked researchers across the globe to find new strategies in the PSM of MOF toward generating functional materials based on MOFs. As a result, several reports on the PSM of MOFs and their applications are published in a bit of time. Further, the PSM methods are more broadened into specific classes, as discussed above. Transmetalation is one of such classes and scientific communities around the globe exploring such methodology to make functional MOFs.

In this regard, we have consolidated the significant results of the transmetalation of MOFs toward application-oriented functional materials. Unlike many elaborated reviews, we briefly discussed the transmetalation approaches, and particular emphasis is given to the applications of MOFs that have been derived via transmetalation. We hope our efforts in the form of this article will help the readers to find a summary of transmetalation PSM methods and applications of modified MOF materials.

2 Post-synthetic Modifications in MOFs

PSMs on MOFs can be broadly divided into four classes: (1) Metal node-based PSM of MOFs, (2) Ligand-based PSM of MOFs, (3) Guest-based PSM of MOFs, and (4) Metal and Ligand-based PSM of MOFs. The present section covers some significant and recent examples of transmetalation PSM methods explored on MOFs and applications of such MOFs in various fields.

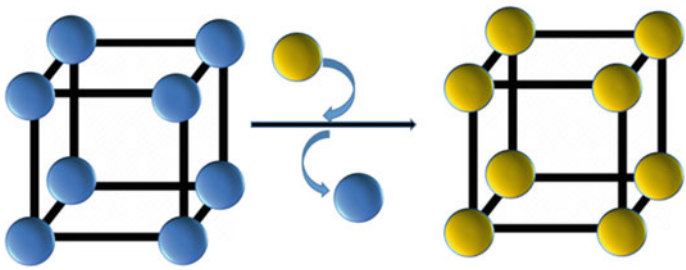
3 Metal Node-Based PSM of MOFs

The exchange of one metal ion with another (Transmetalation), the addition of ligands on coordinatively unsaturated metal nodes, and incorporation of new metal ions are considered and discussed as metal node-based PSM methods in this subsection. Transmetalation is one of such PSM methods extensively explored on MOFs.

3.1 Transmetalated MOFs and Functional Applications

The preparation of desired metal ions containing MOFs from metal ions and corresponding organic linkers often forms undesired structures and topologies, and sometimes, the strategies may also fail. The exchange of metal nodes of existing MOFs with the desired set of metal ions is known as transmetalation. Transmetalation retains the structure and topology of the original MOF and allows us to tune MOFs' electronic and chemical properties. However, transmetalation suffers four significant drawbacks: (1) loss of crystallinity during the PSM synthesis (which is vital to know the structural consistency after PSM), (2) incomplete exchange of host MOF metal ions with the new metal ions, (3) inability of desired metal ions to replace original metal ions in a PSM of MOF, and (4) stability of resulting MOF [31, 46]. The ability of one metal ion to replace another metal ion from a coordination sphere depends on the relative lability. The Irving–Williams stability order of divalent 3d-metal ions (Mn(II) < Fe(II) < Co(II) < Ni(II) < Cu(II) > Zn(II)) can help us to predict whether the desired transmetalation reaction can be possible or not (Scheme 1).

Replacement of Mn(II) ions from the MOF, $Mn_3[(Mn_4Cl)_3(BTT)_8(CH_3OH)_{10}]_2$, using Li^+, Cu^+, Fe^{2+}, Co^{2+}, Ni^{2+}, Cu^{2+}, and Zn^{2+} ions is believed to be the first example of transmetalation PSM [6, 47, 48]. In this example, the transmetalated MOFs are isostructural and structurally identical with the parent MOF irrespective of the type and oxidation state of exchanged metal ions. The study revealed that Mn(II) ions had been replaced by about 91%, by Ni(II) ions, from their parent MOF. The lowest replacement of parent metal ions was observed by univalent metal ions,



Scheme 1 Schematic representation of transmetalation in MOFs

Li(I) and Cu(I). Transmetalated MOFs along with parent MOF were explored for their application as H_2 sorption materials. It is found that the H_2 sorption ability of MOFs is metal ion dependent. The MOF generated from Co(II) ions transmetalation reaction shows maximum H_2 sorption capability compared to other transmetalated MOFs (T-MOFs) [48].

3.1.1 Sensing Applications of T-MOFs

Synthesis of a Ba(II)-based MOF formulated as **$[H_2N(CH_3)_2][Ba(H_2O)(BTB)]$**, where BTB is 1,3,5-benzenetricaboxylicacid, was reported by Asha and coworkers. The edge-shared BaO_9 polyhedra forms 1D polymeric chains, and BTB linkers further connect these 1D polymers to give a 3D network. This MOF platform was transmetalated by Tb(III) ions in a (SCSC) transformation reaction. The crystalline material was soaked for 24 h in a dimethylformamide solution of $Tb(NO_3)_3.7H_2O$ to exchange Ba(II) ions with Tb(III) ions completely. The process is monitored in real time by fluorescence microscope and Fe-SEM–EDX spectroscopy to know the complete metal ion exchange. Upon excitation at 320 nm, the transmetalated **Tb(III) MOF** shows emissions in the UV–visible region at various wavelengths (370, 486, 541, 583, and 618 nm). The emission at 370 nm is due to an LMCT transition. The emission intensity of this LMCT band shows an enhancement when dispersed in an aqueous solution of PO_4^{3-} ions. This unique fluorescent emission property enables this MOF to work as an optical sensor to detect phosphate ions among the other common ions selectively Cl^-, Br^-, F^-, I^-, OAc^-, ClO_4^-, SO_4^{2-}, S^{2-}, NO_2^-, NO_3^-, and CO_3^{2-} in the biological fluids [49] (Figs. 2 and 3).

3.1.2 Catalytic Applications of T-MOFs

Nonquantitative transmetalation of parent MOF can achieve mixed metal MOFs. These partially transmetalated MOFs show excellent catalytic properties due to the synergetic effect of two metal ions. A Ni(II)-based MOF derived from 2,4-dihydroxyterpthalicacid linker was transmetalated with Co(II) by suspending the Ni-MOF in a dimethylformamide solution of $Co(NO_3)_2.6H_2O$ for 4–5 days to yield transmetalated Co–Ni-MOF. The powder X-RD patterns of Ni-MOF and Co–Ni-MOF indicate structural similarity in both MOFs. About 60% of the Ni(II) ions were replaced by Co(II) in the synthesis, and the amount of Ni(II) ions released into reaction solution, analyzed by ICPMS analysis, confirms the % of Co(II) ions loading into the MOF. The original Ni-MOF was inactive as a catalyst in the catalytic oxidation of cyclohexene. However, the Co–Ni-MOF shows improved catalytic activity in the catalytic oxidation of cyclohexene. The improvement is also dependent on the Co(II) loading in the MOF. The authors explained that the cobalt ions could cycle between oxidation states Co(II) and Co(III), an essential property for the catalyst in oxidation reactions [50] (Fig. 4).

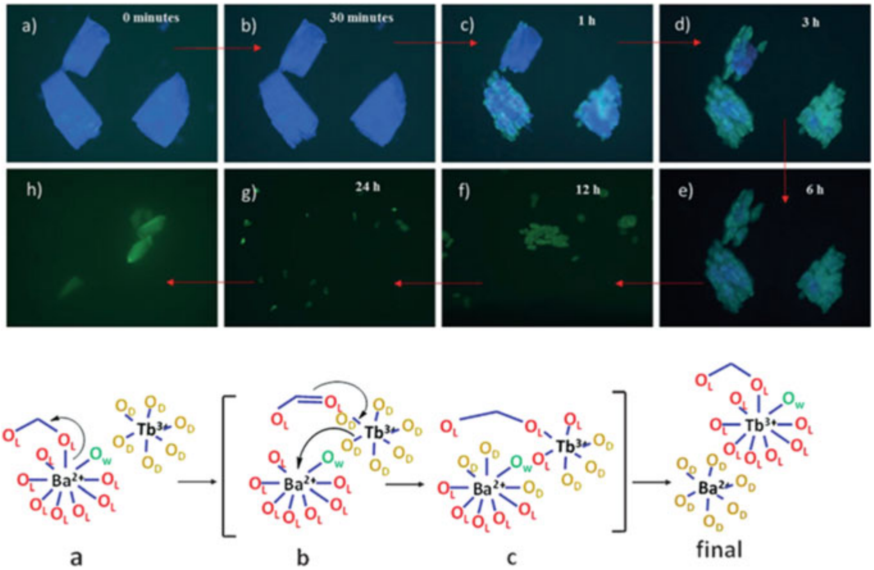


Fig. 2 Analysis of transmetalation process in single crystals of **$[H_2N(CH_3)_2][Ba(H_2O)(BTB)]$** by fluorescent emission microscope (top). The plausible mechanism of transmetalation in crystals of **$[H_2N(CH_3)_2][Ba(H_2O)(BTB)]$** O_L and O_W coordinated ligands from acid linkers and water molecules, respectively; O_D is the oxygen from the solvent molecule. Adapted with permission [49]. Copy right 2016, Wiley–VCH

Metalloporphyrins are known for their excellent catalytic properties [51–53]. Incorporation of such metalloporphyrins into rigid MOFs is an outstanding achievement. A synthesis of Cd(II)-based MOF, **porph@MOM-10**, derived from $CdCl_2$, biphenyl-3,4′,5-tricarboxylate (H_3BPT), and *meso*-tetra (N-methyl-4-pyridyl) porphinetetratosylate (TMPyP) was reported by Zhang et al. [54] **Porph@MOM-10** was found to exhibit transmetalation with Mn(II) and Cu(II) ions and forms corresponding transmetalated MOFs **Mnporph@MOM-10-Mn** and **Cuporph@MOM-10-CdCu**. The transmetalation process is carried out in methanolic solutions of $MnCl_2$ and $CuCl_2$, and the reaction solution is replaced with a fresh solution for every 24 h. The process monitored by spectral methods, UV–Visible spectroscopy, and AAS spectroscopy revealed that Mn(II) ions replaced the Cd(II) ions of porphyrin moiety in one week, and for the network Cd(II) ions, it took one month for the complete exchange. At the same time, Cu(II) ions replaced the Cd(II) ions of porphyrin moiety in 3 days. However, the network Cd(II) ions are partially replaced, 73%, even after one month. The catalytic performances of these MOFs were studied for the *trans*-stilbene epoxidation reactions. The results indicated that the parent **Porph@MOM-10** shows only 7% of the conversion of stilbene to stilbene oxide and benzaldehyde. Under similar reaction conditions, the transmetalated MOFs, **Mnporph@MOM-10-Mn,** and **Cuporph@MOM-10-CdCu**, show