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Research Article

The use of Statistical Methods in Mechanical Engineering

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Abstract: Statistics is an important tool to handle the vast data of present era as statistics can interpret all the information in such a beauty that so many conclusions can be extracted from it. The aim of this study is to see the use of statistical methods in Mechanical Engineering (ME) therefore; we selected research papers published in 2010 from the well reputed journals in ME under Taylor and Francis Company LTD. More than 350 research papers were downloaded from well reputed ME journals such as Inverse Problem in Science and Engineering (IPSE), Machining Science and Technology (MST), Materials and Manufacturing Processes (MMP), Particulate Science and Technology (PST) and Research in Nondestructive Evaluation (RNE). We recorded the statistical techniques/methods used in each research paper. In this study, we presented frequency distribution of descriptive statistics and advance level statistical methods used in five of the ME journals in 2010.

Keywords: Descriptive statistics, mechanical engineering, statistical methods

INTRODUCTION

Statistical methods have been widely used in decision making. The role of statistics is widely accepted and acknowledged as a powerful instrument in the scientific research activities. The popularity and great increase in the use of statistical techniques has been observed for a wide range of medical and other journals over the past few decades (Altman, 1982, 1991 and 2000; Strasak, 2007). They are successfully appealing the researchers working in various environments. They are helpful in fitting as well as prediction of statistical models related to any field of interest e.g. Economics, Sociology, Psychology etc. Statistical methods became one of the most important elements of today's research. Many studies have been published to highlight the usefulness and appropriateness of these methods. In general, statistical methods used for various kinds of data analysis can be categorized into two major parts:

- Parametric methods
- Non-parametric methods

Earlier methods are used when the parameters of the distribution are specified and later methods are used when no specified parameters of the distribution are given. Now days, the use of statistical methods in various fields including for example, astronomy, banking, economics, mathematics, meteorology, sociology, computer sciences, engineering, medical sciences, industries, agriculture and business study's have increased a great extent. These methods are used to present the data effectively, help in critical analysis of information and summarizing the large data into a simple form using the frequency distribution and graphs. According to Altman (1982, 1991, 2000) and Strasak (2007), statistics is a powerful tool for analysis, interpretation of medical data and uses of statistical methods in medical sciences have been seen in medical journals. Now days, several advanced statistical software are available for the analysis of data. But, the use of t-test and Chi-square test remain in commend use. For more detail, reader may refer to Emerson and Colditz (1983), Colditz and Emerson (1985), Menegazzi *et al*. (1991), Cardiel and Goldsmith (1995), Huang *et al*. (2002) and Reed III *et al*. (2003). Recently, Zaman *et al*. (2011) studied statistical methods in recent surgical research.

The ME journals have also widely used the statistical methods for the survival and reliability of machineries. By exploring the literature we found that there is no work on descriptive statistics of methods in ME. The purpose of this study is to explore the use of statistical methods in ME journals. We selected study's published in 2010 from the well reputed journal in ME from Taylor and Francis Company LTD. More than 350 study's were downloaded from well reputed ME journals such as Inverse Problem in Science and Engineering (IPSE), Machining Science and Technology (MST), Materials and Manufacturing Processes (MMP), Particulate Science and Technology (PST) and Research in Nondestructive Evaluation (RNE). We recorded the statistical techniques/methods used in each study. In this study, we will present frequencies distribution and descriptive statistics of

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statistical methods used in ME. Further, we will compare the use of statistical methods in ME journals and surgical Journals. This study was conducted in department of Statistics, Forman Christian College University Lahore in 2012.

MATERIALS AND METHODS

As mentioned earlier that the research studies were collected from Taylor and Francis Company in the field of ME. These study's were published during the year 2010 in volume 8, Number 1-8 of IPSE , Volume 14 , Numbers 1-4 of MST, Volume 25, Number 1-12 of MMP, Volume 28, Numbers 1-6 of PST, Volume 21, Numbers 1-4 of RNE. Forwards, editorial boards, case reports and review studies were excluded, but the special issues were included in study. For Statistical content each study were manually reviewed and noted down the statistical techniques used in it. The frequencies of methods being used in journals are recorded in 14 categories similarly as in Zaman *et al*. (2011). The basic tools and techniques of statistics were classified into "descriptive statistics" and the techniques related to sampling were included in "inferential statistics". The analysis (Fisher information analysis, finite element analysis, sensitivity analysis, error analysis, damaged identification analysis, empirical analysis, first law of thermodynamic analysis, stereo analysis, structural analysis, inverse analysis, dynamic analysis, quality analysis, stability analysis, stress analysis, theoretical analysis, elastoplastic analysis, systematic data analysis, quantitative texture analysis, structural analysis, spectrum analysis, analysis of thermal partition, parametric analysis, quantitative analysis, rotor dynamic analysis, walvet packet analysis, slip-line analysis, statistical analysis, model-based analysis, thermal analysis, Energy Dispersive X-ray spectroscopy analysis (EDS), Finite Element (FE) analysis, X-Ray Diffraction (XRD) analysis, Dead Metal Zone (DMZ) analysis, Scanning Electron Microscope (SEM) analysis, numerical analysis, cyotoxicity analysis, micro structural analysis, compositional analysis, sieve analysis, EDAX analysis, X-ray line scan analysis, chemical analysis, grey rational analysis, experimental analysis, dimensional analysis, differential thermal analysis, TEM analysis, grain size analysis, thermo gravimetric analysis, micro analysis, Fourier Transform Infrared analysis (FTIR), thermogravimetry-differential thermal analysis, X-ray analysis, elastic-plastic analysis, element analysis, unbiased analysis, process capability analysis, spring back analysis, optical microscopy analysis, qualitative analysis, Rosenthal's analysis, defect analysis, thermo mechanical finite element analysis, image analysis, Johonson-Mehl-Arvani analysis (JMA), Genetic Algorithm (GA) analysis, analysis of hydrodynamics, response surface analysis, Elemental Analysis (EA), stress analysis, optimization analysis, surface analysis, Atomic Force Microscopy (AFM) analysis, EDX analysis, Glow Discharge Optical Spectrometry (GDOS) analysis, analysis of stress distribution, structure analysis, Root Mean Squared Deviation (RMSD) analysis, real model analysis, Finite Element Model (FEM) analysis, analysis of microstructure, Electron Bank Scattered Diffraction (EBSD) analysis, thermodynamic analysis, Nitrogen analysis, Leica Image Analysis System, time-dependent 2D analysis, POD analysis, structural integrity analysis, joint time-frequency analysis, subsequent analysis, nondestructive analysis, Receiver Operating Characteristic (ROC) analysis, visual analysis, Principal Component Analysis (PCA), Artificial Neural Networks (ANNs) analysis, thermal stability behavior analysis, time domain analysis, XRF analysis, particle size distribution analysis, high resolution topographical analysis, commercial data analysis, microbial analysis, topographic analysis, structure factor analysis, Guinier analysis, dimensional analysis, Pareto analysis, method of light scattering analysis, finite element stress analysis, deconvolution analysis, spectral analysis, Gas Chromatograph (GC) analysis, scion image analysis, Extended X-ray Absorption Fine Structure (EXAFS) analysis, model dependent analysis, symmetry analysis, variance metrics analysis, uniformity analysis, dimensional analysis, Debye function analysis) used in the journal studies by engineers rather than statistical analysis are categorized in "Engineering Analysis". And the statistical analyses were represented by their names. Thereby, regression models, scatter plots, errors (bias), experimental error, random error, systematic error, sum of the square of errors, relative errors, error estimates, absolute error, constant variance error, uncorrelated error, the Gaussian distribution of errors, measurement error, data error, identification error, numerical error, experimental error, accumulated error, consequent error, residual error, significant error, mean prediction error, roundness error, margin of error, RMS error, least square error, error variance, manufacturing error, average dimension error, spindle encoder error, angular sensitivity error, standard deviation for error, fundamental error, segregativity error, mean fractional error, systematic measurement error and multiple regression models are included in the category of "regression analysis". ANOVA methods include ANOVA test and F-test. In the same way category of "confidence interval" have the p-value, level of significance and confidence intervals. The distributions (normal distribution, binomial distribution, exponential

distribution, gamma distribution, etc.) were categorized in "probability distribution". Study's containing least square methods, Bayesian methods, Cramer-Rao bounds, maximum likelihood estimator, Danieli's coil quality estimator, inverse parameter estimation, statistical estimation problem were included in "estimation". After this, in each study different statistical techniques were observed and counted in order to determine the involvement of statistics in each study. A comparison based on percentage of number of statistical methods used in surgical journals (Zaman *et al*., 2011) and ME journals (present study) is developed.

RESULTS

The total number of study's downloaded from IPSE were 64, 25 study's were downloaded from MST, 43 study's were downloaded from PST, 15 study's were downloaded from RNE and 212 study's were downloaded from MMP. Table 1 shows statistical techniques, frequencies and there percentages, those have been applied in the study's. From Table 1, we can see that the descriptive statistics is at the top among the statistical methods used in ME journals. Descriptive statistics was used 150 times in 359 journals. We also note that Markov model is not a popular technique in ME. This model was applied only 1 time in 359 journals.

Table 2 shows the percentages of various statistical methods being used in ME journals. Overall, 359 study's have been reviewed, out of which 13.6% covers descriptive statistics methods, 30.6% contains methods of inferential Statistics, 22.3% have correlation analysis, 29% are from regression analysis and 54% includes engineering analysis. Individually studies from each journal have also been considered from which IPSE consists of 64 studies, from that 32.8% contains descriptive statistical methods, 26.6% includes inferential statistical methods, 20.3% contains correlation process, 56.2% have regression models and 35.9% are from engineering analysis. According to MST, overall 25 study's were investigated and from their 16% are methods of descriptive statistics 28% contains inferential methods of statistics, 40% encloses correlation analysis, 44% includes regression analysis and 68% contained engineering analysis. Likewise 43

Table 1: Frequency distributions of methods in ME journals

	IPSE n = 64	MST n = 25	PST n = 43	RNE n = 15	MMP n = 212	All journals n = 359
No statistical methods	6	4	4	0	35	49
Descriptive statistics	21	4	30	9	86	150
Inferential statistics	17	7	18	10	58	110
Probability distribution	26	5	12	4	36	83
Engineering analysis	23	17	29	10	115	194
Correlation analysis	13	10	13	6	38	80
Regression analysis	36	11	12	7	38	104
Experimental design	2	3	4	1	7	17
Confidence interval	3	6	10	2	15	36
Reliability	2	2	7	5	14	30
Stochastic process	6	1	0	2	8	17
Estimation	22	3	2	3	13	43
Markov model	1	0	0	0	0	1
ANNOVA test	0	4	1	1	24	30

Table 2: Percentage of frequency distributions of methods in ME journals

	IPSE n = 64	MST n = 25	PST n = 43	RNE n = 15	MMP n = 212	All journals n = 359
No statistical methods	6 (9.4)	4 (16)	4 (9.3)	0 (0.0)	35 (16.5)	49 (13.6)
Descriptive statistics	21 (32.8)	4 (16)	30 (46.9)	9 (60)	86 (40.6)	150 (41.7)
Inferential statistics	17 (26.6)	7 (28)	18 (41.9)	10 (66.7)	58 (27.4)	110 (30.6)
Probability distribution	26 (40.6)	5 (20)	12 (27.9)	4 (26.7)	36 (16.98)	83 (23.1)
Engineering analysis	23 (35.9)	17 (68)	29 (67.4)	10 (66.7)	115 (54.2)	194 (54)
Correlation analysis	13 (20.3)	10 (40)	13 (30.2)	6 (40)	38 (17.9)	80 (22.3)
Regression analysis	36 (56.2)	11 (44)	12 (27.9)	7 (46.7)	38 (17.9)	104 (29)
Experimental design	2 (3.1)	3 (12)	4 (9.3)	1 (6.7)	7 (3.3)	17 (4.7)
Confidence interval	3 (4.7)	6 (24)	10 (23.3)	2 (13.3)	15 (7.1)	36 (10)
Reliability	2 (3.1)	2 (8)	7 (16.3)	5 (20)	14 (6.6)	30 (8.4)
Stochastic process	6 (9.4)	1 (4)	0 (0.0)	2 (13.3)	8 (3.8)	17 (4.7)
Estimation	22 (34.4)	3 (12)	2 (13.3)	3 (20)	13 (6.1)	43 (12)
Markov model	1 (1.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.27)
ANNOVA test	0 (0.0)	4 (16)	1 (6.7)	1 (6.7)	24 (11.3)	30 (8.4)

Table 3: Percentage of different statistical methods

	IPSE n = 64	MST n = 25	PST n = 43	RNE n = 15	MMP n = 212	All journals n = 359
Only 1 method	11 (17.2)	3 (12.0)	76 (36.0)	15 (35.0)	2 (13.3)	107 (30.0)
2 or 3 methods	30 (47.0)	9 (36.0)	63 (30.0)	20 (46.5)	5 (33.3)	127 (35.4)
4 or 5 methods	13 (20.3)	7 (28.0)	16 (9.0)	6 (14.0)	7 (47.0)	49 (14.0)
More than 5 methods	5 (8.0)	1 (4.0)	8 (4.2)	1 (2.3)	1 (7.0)	16 (4.5)
No/unidentified statistical methods	5 (8.0)	5 (20.0)	49 (24.0)	1 (2.3)	0 (0.0)	60 (17.0)

Table 4: Comparisons of method being used in ME journals and surgical research journals

	ME journals n = 359 (%)	Surgical journals n = 518 (%)
Only 1 method	30.0	9.1
2 or 3 methods	35.4	31.3
4 or 5 methods	14.0	18.5
More than 5 methods	4.5	14.5
No statistical methods	17.0	26.1

study's were reviewed from PST, from here 46.9% have descriptive statistical methods, 41.9% covers inferential methods of statistics, 30.2% covers correlation analysis, 27.9% contains regression analysis and 67.4% covers engineering analysis. The RNE consisted of 15 studies for study, from which 60% includes descriptive statistical methods, 66.7% add in methods of inferential statistics, 40% covers analysis of correlation, 46.7% contains regression analysis and 66.7% consists of engineering analysis. The fifth journal MMP had 212 studies for investigation, from that 40.6% obtains descriptive statistical methods, 27.4% are inferential statistical methods, 17.9% includes correlation analysis, 17.9% contains regression analysis and 545.2% contained engineering analysis.

Table 3 shows the percentage of different number of statistical methods used in ME journals. From Table 3, we can note that one method is used 30% in all journals. Two or three methods used 35.4% in all journals and the percentage of more than 5 methods used in all journals is 16%. In PST, the percentage of use of one method is 36% that is higher than other journals.

Table 4 represents the comparison between the uses of statistical methods in ME journals with Zaman *et al*. (2011). From this table, it is very interesting to note that in surgical research journal, the percentage of use of no statistical methods is 26.1% while it is 17% in ME journals which indicate that ME journals are applying these methods more than surgical research journals. The percentage of only one method in ME journal is 30% which is also higher than the surgical journals.

CONCLUSION

As we can see from Table 1 that mostly journals have used the descriptive methods of statistics. The journals applied descriptive statistics are IPSE and MST uses least of it. Whereas Markov model is the least method used in the journals to test reliability. Other statistical techniques such as inferential methods of statistics, regression analysis, correlation, etc., are successfully applicable over the data. Complexities of statistical data analysis of surgical journal and mechanical engineering journals have almost similarity of using statistical techniques of equal ranges. The confidence interval by estimating effect sizes gives the information data to engineers and researchers that they need. These results suggest that in future investigation, statistics will play major role in the field of engineering. Recently, the study used ME journals have chosen to collect data and apply statistical techniques to check the importance of statistics in engineering sciences. So, different fields such as education, health science, agriculture, etc., research studies will also be used to follow up these. And different methods will be applied to check relation as well as significance difference among information or data. We observed low percentage of (less than 10%) "No Statistical Methods" used in IPSE, RNE and PST. Similarly, the percentage is 16, 16.5 in two of the journals MST and MMP respectively. It is found that RNE is the only journal where statistical methods are used in all the considered studies. The journals considered in the present study are mainly focusing on descriptive statistics, inferential statistics, probability distributions, engineering analysis, estimation, correlation analysis and regression analysis. While some advance level techniques including experimental design, confidence interval, reliability and stochastic process are used less frequently.

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