Group Technology Application in Preventive Maintenance

By

Hamid Seifoddini

Associate Professor

And

Abdelhakim Abdelhadi

PhD Candidate

Industrial and Manufacturing Engineering Department

University of Wisconsin – Milwaukee

Milwaukee, Wisconsin

Abstract: In this paper the similarity coefficient method based on the concept of group technology is applied to form virtual cells of machines/equipment with similar maintenance requirements. The planning and scheduling of maintenance operations according to the requirements of such cells will simplify these operations leading to better operational efficiency.

Introduction

Preventive maintenance is the foundation of efficient, reliable, and smooth running manufacturing systems of today. The critical role of preventive maintenance is, particularly, paramount in the operation of lean manufacturing systems which require high levels of machine reliability. As such, the improvement of preventive maintenance operations leads to higher performances in the manufacturing operations [1,3,9].

Preventive maintenance encompasses all activities necessary to keep a facility in a good operational condition. The planning, coordination, and execution of such activities in manufacturing environments constitutes a highly complex system of operations due to a large number of machinery and auxiliary equipment involved. Despite the enormity, diversity, and complexity of plant equipment, a vast majority of means of production are composed of simpler modules of electronic, mechanical, and computerized components which experience similar types of failures and require similar maintenance operations. These similarities can be exploited to streamline maintenance operations by devising group scheduling and execution of maintenance activities. Such an efficient approach to maintenance in manufacturing facilities can be a based on group technology.

Group technology, in general, is a concept which utilizes the similarities of process/ objects to generate a single solution to a set of similar problems. Group technology has been successfully applied in manufacturing operations for learn production [5, 6, 10]. The application of group technology to manufacturing is cellular manufacturing. In cellular manufacturing parts with similar manufacturing requirements are grouped into part-families and machines processing one or more part-families are organized into machine cells. This allows scheduling, testing, transportation, etc. be done according to part-families rather than individual parts leading to setup reduction, lower inventory, and more efficient and effective planning and execution of manufacturing operations[2,6,7]. The concept of group technology can also be applied to maintenance activities for more efficient and effective maintenance operations.

In this paper group technology is proposed as a solution to the maintenance operations of manufacturing facilities. A new similarity coefficient will be developed which incorporates the maintenance data including failure types into the organization of maintenance operations according to the concept group technology.

Background

Total productive maintenance refers to the collections of scheduled maintenance activities necessary to keep means of production in top operating conditions. Due to the large number of machines and auxiliary equipment in manufacturing systems and the need for timely and economical employment of maintenance resources including labor and materials, the planning, scheduling, and execution of maintenance operations are complex and expensive[4,8]. Any systematic approach to maintenance operations in manufacturing systems has a great

potential for savings. Computer simulation has been employed for the comparison of different types of maintenance practices. ABC classification has been also used to prioritize maintenance operations according to the significance of productions processes and equipment. Group technology which has been credited for the reductions of setup times and simplification of material flow in lean production systems has a great potential for efficiency improvement of maintenance operations by exploiting the underlying similarities of failure types and recovery operations for a variety of electronic, mechanical, and mechatronic components of manufacturing machinery and equipment.

Group Technology Application in Preventive Maintenance

The similarity coefficient method based on the concept of group technology is one of the methods used for the formation of machine cells in production systems. In preventive maintenance, it is not necessary to form actual machine/equipment cells. Virtual cells which identify machines/equipment with similar maintenance requirement can be the basis for the application of group technology to preventive maintenance. To form such virtual cells a similarity coefficient between pair of machines/equipment is defined as follows [6,7]:

$$S_{ij} = \frac{\sum_{k=1}^{n} X_{ijk}}{\sum_{k=1}^{n} Y_{ijk}}$$

Where: S_{ij} = similarity coefficient between machines *i* and *j*.

$$X_{ij} = \begin{cases} 1, if\ both\ machine\ experience\ the\ same\ type\ of\ failure \\ 0,\ otherwise \end{cases}$$

And

$$Y_{ijk} = \begin{cases} 1, if\ either\ one\ of\ machines\ i\ or\ j\ experiences\ failure\ type\ k \\ 0,\ otherwise \end{cases}$$

$$n = number\ of\ failure\ types$$

Using this similarity coefficient, a similarity matrix containing all pair-wise similarity coefficients between machines/equipment will be developed. The next step in the formation of virtual cells is the use of a clustering algorithm to group machines/equipment together based on their level of similarity. Among clustering algorithms, the single linkage clustering (SLINK) has been widely used due to its simplicity. In this paper SLINK will be employed to identify the virtual cells[6].

The procedure for forming virtual machine/equipment cells for preventive maintenance can be summarized as follows:

1. Identify all machines/equipment as well as all type of possible failures

2. Developing a failure-machine/equipment chart similar to machine-component matrix in cellular manufacturing.
3. Calculate all pair-wise similarity coefficients and organize them in a similarity matrix
4. Use SLINK to form a dendogram representing virtual cells of machines/equipment
5. Organize the data in dendogram into a failure- machine/equipment matrix.

The failure- machine/equipment matrix provides valuable information on the similarities of machine/equipment in terms of their maintenance requirement.

Example

The following numerical example illustrates the proposed methodology to create preventive maintenance virtual cells. The data in Table (1) shows a failure-machine matrix for seven machines used in a facility to separate mineral salts using the evaporation of water method, while table (2) explains the failures listed in table (1).

Failure Type

Machine /Equipment	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
1:Fluidizer, L1	1	1				1	1	1			
2:Compressor, L11			1	1	1				1	1	
3:Compressor, L2			1	1	1					1	
4:Blower, L2			1	1		1			1		
5:Mixer, L12	1	1				1	1	1			
6: Steam Trap, L12											1
7: Pump,L12	1	1					1	1			

Table (1) shows a failure-machine matrix

Failure	Description	Failure	Description
F1	Fails to start	F7	Speed too high
F2	Excessive power demand	F8	Improper lubrication
F3	Delivery less than rated capacity	F9	Motor failure
F4	Excessive vibration	F10	Insufficient flow
F5	Piston ring /piston cylinder wear excessive	F11	Back pressure too high
F6	Stopped while running/Trip		

Table (2) Descriptions of failures used in table, (1)

Following the procedure in page 3, the similarity matrix for this problem is constructed [Table 3]

Machine /Equipment

Equipment	1	2	3	4	5	6	7
1	X						
2	0	X					
3	0	0.8	X				
4	0.1	0.6	0.3	X			
5	1	0	0	0.1	X		
6	0	0	0	0	0	X	
7	0.8	0	0	0	0.8	0	X

Table (3), Similarity Coefficient Matrix

Based on the similarity coefficient matrix a Dendogram is developed and used to establish the virtual cells according to their associated failures types.

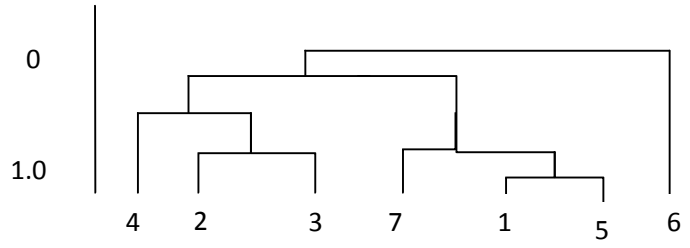

Figure (1) Dendogram

The abscissa of the Dendogram represents the machines/equipment. The similarity coefficient scale, having a range of 0.0 to 1.0 is represented in the ordinate. We will apply the single linkage clustering technique to form the virtual cells, which evaluates the similarity between two machines groups as follows: the pair of machines with the highest similarity coefficient is grouped together. This process continues until the desired numbers of machine groups have been obtained or all machines have been combined in one group based on a threshold value. Looking at the Dendogram we can see that at 100% similarity coefficient machines 1 and 5 are grouped together and form the first cluster. At similarity value of 0.8, machines 2 and 3 are grouped together and machines 7 clustered with machines 1 and 5.

Let us consider three different possible scenarios to the failure-machine problem. Scenario 1 is the trivial solution consisting of a single virtual cell containing all machines which occurs at zero similarity between all machines. The second scenario is at least, at 50% similarity between machines. This scenario will create 3 different virtual cells containing the following

machines: {2, 3, and 4}, {7, 1, and 5}, {6}. It is clear that machine 6 is a bottleneck machine (can join more than one virtual cell group).

At 75% similarity, the following virtual cells are created: {4}, {2, and 3}, {7, 1, and 5} and {6}. Table (4), present the failure types associated with each virtual cell.

Table (4), Virtual cells and the associated failures at 75% similarity level

Machine /Equipment	Failure Types										
	F3	F4	F5	F6	F9	F10	F1	F2	F7	F8	F11
4	1	1		1	1						
2	1	1	1		1	1					
3	1	1	1			1					
7							1	1	1	1	
1				1			1	1	1	1	
5		1		1			1	1	1	1	
6											1

This example illustrates that machines were grouped in virtual cells based on the failure they encounter, which will help to create a unique preventive maintenance for each group. The size of each cell can be adjusted depends on the requirements of each manufacturer such as the availability of the maintenance personal.

Conclusion

In this paper a procedure for the application of group technology to preventive maintenance was presented. The procedure involves the use of similarity coefficient method in the formation virtual machine/equipment cells. These cells, which contain machines/equipment with similar maintenance requirements, can be used to simplify preventive maintenance operations.

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