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APPLICATION OF FAFF FOR THE DESIGN OF PART FAMILIES IN AN AUTOMATED COMPANY – A CASE STUDY

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ABSTRACT

When machine cells could be made out of general CNC machines with appropriate tooling, group technology is then faced with the task of generating part families without looking at the concurrent formation of machine cells. In these situations the parts alone need be grouped into families based on their design attributes called features. This paper presents an application for part family formation, in an engineering company. The methodology applied here is: *FAFF* (Family Formation by Features) - for the formation of part families in group technology, based on the similarity of part features. The results obtained are found more satisfactory.

Key Words*: Part Family Formation, Group Technology, Family index*

1. Introduction

The need for increasing productivity in batch manufacturing has led to the concepts of group technology (GT) and cellular manufacturing (CM). Group technology is a manufacturing philosophy in which similar parts are identified and grouped together to take advantage of their similarities in manufacturing and design. Similar parts are arranged into part families. Each family would possess similar design and manufacturing characteristics. Hence, the processing of each member of a given family would be similar and this results in manufacturing efficiencies. These efficiencies are achieved in the form of reduced set up times, lower work in process inventory, better scheduling improved tool control and the use of standardized process plans.

In group technology, there are some situations where concurrent classification of parts and machines is neither possible nor necessary. As machine cells could be made out of general CNC machines with appropriate tooling, group technology is now faced with the task of generating part families without looking at the concurrent formation of machine cells. In these situations the parts alone need be grouped into families based on their design attributes called features.

In this paper, the methodology considered is: Faff (FAmily Formation by Features). P.Venkata Chalapathi and Dr.YVSSSV.Prasada Rao (2006), Part FAmily Formation by Features (FAFF) in Group Technology, can be referred for complete details of the method. It groups the parts into families based on similarity of features. These features are of two types: nominal features and interval features. FAFF is an algorithm to find the natural cluster structure in such mixed data. Goodness of the resulting families is measured by 'family index', given in the same article. The algorithm of FAFF is recalled and presented below.

2. FAFF – Algorithm

1. Input the data: no. of parts, no. of nominal features, no. of interval features, weight, nominal feature matrix, and interval feature matrix
2. Normalize the interval features
3. Find the similarity coefficients for nominal features and for interval features
4. Find the total similarity coefficients and distances
5. Find mean and standard deviation for all similarity coefficients
6. Do for c=-1.0,-0.9,…………,0.9,1.0
   i) Calculate threshold value-T
      if ($T \leq 0$) go for next value of c
      if ($T \geq 1$) stop
   ii) Find the natural seeds
   iii) Form the part families
   iv) Compute the family index-f_i for the obtained families
7. Take the best part families, based on high family index
8. End

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3. Design of Part Families in xyz Company

FAFF methodology was successfully applied in XYZ company, situated near by Vijayawada, Krishna District, Andhra Pradesh, India. The company is using all CNC machines to produce the parts. Most of the parts are getting processed on any single machine. Here, concurrent classification of parts and machines is neither possible nor necessary and the parts alone need to be grouped without considering the formation of machine cells. 36 parts and 15 features (5-nominal features & 10-interval features) are considered for the design of part families in XYZ Company. Weight for nominal features is given as 1/3 and for interval features as 2/3, depending on the number of features. The details of parts features are given below.

No	Nominal Features
1	External shape
2	Internal shape
3	Material type
4	Finishing
5	Chamfering
No	Interval Features
6	External Steps
7	Internal Steps
8	Taper
9	Cylindrical Grooves/Holes
10	Surfaces
11	L/D Ratio
12	Tolerance
13	Surface Finish
14	Threads
15	Teeth

P.No.	External Shape	Internal Shape	Material Type	Finishing	Chamfering
1	Cylindrical-1	Cylindrical-1	Brass-2	0	0
2	Rectangular2	Elliptical Grooves-3	Al Alloy-1	0	0
3	Cylindrical-1	Cylindrical-1	Al Alloy-1	0	0
4	Cylindrical-1	Cylindrical-1	Al -1	Plating and Anodizing-1	0.25X45º
5	Cylindrical-1	Cylindrical-1	Al 64430-1	0	0
6	Threaded-5	Irregular-0	St Steel 17-4PN-3	0	0.25X20º
7	Cylindrical-1	Cylindrical-1	Al 64430-1	Anodized-2	0
8	Cylindrical-1	Cylindrical-1	Al 64430-1	Plating-3	0.25X45º
9	Square-4	Cylindrical-1	Al 64430-1	0	0
10	Square-4	Cylindrical-1	Al 64430-1	0	0
11	Cylindrical-1	Threaded-5	Phospor Bronze-4	Anodizing	0
12	Rectangular-2	Cylindrical-1	Al Alloy-1	0	0
13	Rectangular-2	Elliptical Grooves-3	Al 24345-1	Black Anodizing-4	0
14	Rectangular-2	Elliptical Grooves-3	Al Alloy 6061-T6-1	0	0
15	Rectangular-2	Elliptical Grooves-3	SAE Al Alloy 6061-T6-3	Black Anodizing	0
16	Square-4	Cylindrical-1	Al 64430-1	0	0
17	Cylindrical-1	Cylindrical-1	Al 64430-1	0	0
18	Cylindrical-1	Cylindrical-1	Al 64430-1	0	0
19	Rectangular2	Elliptical Grooves-3	Al Alloy 6061-T6-1	0	0
20	Cylindrical-1	Cylindrical-1	Bronze PH RND 22.49-4	0	0
21	Cylindrical-1	Cylindrical-1	St Steel A ISI 304-3	0	0
22	Square-4	Cylindrical-1	Al Alloy-1	0	0
23	Cylindrical-1	Cylindrical-1	SST RND55-3	0	0
24	Square-4	Cylindrical-1	Al Alloy 6061-T6-1	Chemical Conversion-5	2.5X45º
25	Cylindrical-1	Cylindrical-1	Brass FM RND 125-2	Black Nickel-6	0

26	Cylindrical-1	Cylindrical-1	Al Alloy-1	Anodized	2.5X45º
27	Cylindrical-1	Cylindrical-1	Brass FM RND 18-2	0	0
28	Cylindrical-1	Cylindrical-1	Al 64430-1	0	0.25X45º
29	Cylindrical-1	Cylindrical-1	Al 64430-1	0	0.5X45º
30	Cylindrical-1	Cylindrical-1	Al 64430-1	0	0
31	Cylindrical-1	Cylindrical-1	Al 64430-1	Straight Knurling,0.75P-7	0
32	Irregular-0	Cylindrical-1	Al 64430-1	0	0
33	Rectangular2	Threaded-5	Phospor Bronze-4	0	0.25X45º
34	Cylindrical-1	Threaded-5	SST RND 12-3	0	0
35	Rectangular2	Threaded-5	Phospor Bronze-4	0	0.25X45º
36	Cylindrical-1	Cylindrical-1	Al 64430-1	0	0

The details of part interval features are given below

P.No.	External Steps	Internal Steps	Taper	Cylindrical Grooves/Holes	Surfaces	L/D Ratio	Tolerance	Surface Finish	Threads	Teeth
1	1	1	0	1	2	4.6/16.5=0.2788	-0.03	10μ	0	0
2	0	4	0	7	6	0	±0.01	1.6μ	0	0
3	4	7	30º	5	8	30.82/31=09942	±0.01	1.6μ	M24	0
4	0	0	0	1	2	2.5/39=0.04612	±0.01	10μ	0	0
5	0	4	30º	3	6	14.5/30=04833	±0.01	0.8μ	0	0
6	13	0	20º	1	15	51.6/7.6=6.7894	±0.01	1.6μ	M5X0.75	0
7	0	2	0	2	3	5.3/22=0.2409	±0.01	0.8μ	M25X0.75	0
8	0	1	38º	1	4	6/28=2143	±0.01	1.6μ	0	0
9	5	5	0	2	7	0	±0.01	0.8μ	0	0
10	4	1	0	1	7	0	±0.01	1.6μ	4-M4X6deep	0
11	1	1	0	1	5	9.8/9.25=1.0594	±0.5	0.8μ	M5X0.75	0
12	2	1	0	2	6	0	±0.01	1.6μ	0	0
13	5	2	53.5º	5	5	0	±0.01	1.6μ	0	0
14	1	1	15º	2	4	0	±0.05	1.6μ	0	0
15	3	4	0	2	5	16.3/24=0.692	±0.05	1.6μ	M1	0
16	2	2	0	4	6	53.5/32=1.6719	±0.01	0.8μ	Metric	0
17	4	5	0	1	7	54/54=1	±0.01	0.8μ	M40X1P	0
18	0	1	0	0	2	5/27=01852	±0.01	0.8μ	M26X0.5P	0
19	2	1	0	8	4	0	±0.01	1.6μ	M4X8,M3X6	0
20	0	1	0	1		6/20.36=02947	±0.01	0.8μ	0	14
21	4	1	0	2		6/38=01578	±0.01	0.8μ	0	38
22	2	2	0	4	4	52/15=3.4666	±0.01	1.6μ	0	0
23	0	1	0	3	4	11/64=.1719	±0.01	1.6μ	0	125
24	5	5	0	4	6	32/28=1.1429	±0.01	0.8μ	0	0
25	0	1	0	9		8/119.062=0.0672	±0.01	1.6μ	0	300
26	4	3	30º	3	6	6.6/29.2=.2260	±0.01	0.8μ	M21.5X0.75	0

27	2	0	75º	1	2	7.05/16.5=.42727	±0.01	0.8µ	0	0
28	1	3	26.6º	0	4	2.75/27=.10185	±0.01	0.8µ	0	0
29	0	5	0	1	6	9.3/21.2=.4387	±0.01	0.8µ	M21X0.5P	0
30	1	1	27.5º	1	4	7.3/26=.2807	±0.01	0.8µ	0	0
31	3	2	0	1	7	19/36=.5277	±0.01	0.8µ	M34X12	0
32	4	3	0	1	6	22/27=08148	±0.01	1.6µ	0	0
33	0	0	0	1	1	5/11=.4545	±0.01	1.6µ	M4X0.25	0
34	9	0	0	21	1	43.8/6.3=2.1904	±0.01	1.6µ	M4X0.25	0
35	3	0	60º	1	3	6.5/5=1.3	±0.01	0.8µ	M4X0.25	0
36	5	7	45º	3	10	29.5/31.5=0.9365	±0.01	1.6µ	M30X0.25	0

Codes are given for the nominal features as follows:

EXTERNAL/ INTERNAL SHAPE		FINISHING	
Shape	Code	Finishing	Code
Cylindrical	1	Plating and Anodizing	1
Rectangular	2	Anodized	2
Elliptical Grooves	3	Plating	3
Square	4	Black Anodizing	4
Threaded	5	Chemical Conversion	5
Irregular	0	Black Nickel	6
		Straight Knurling	7
MATERIAL TYPE			
Material	Code	CHAMFERING	
Aiuminium	1	Chamfer	Code
Brass	2	Chamfering	1
Steel	3	No chamfering	0
Phospor Bronze	4		

Considering the above codes for nominal features, the total part-feature matrix is:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1	2	1	1	1	5	1	1	4	4	1	2	2	2	2	4	1	1
2	1	3	1	1	1	0	1	1	1	1	5	1	3	3	3	1	1	1
3	2	1	1	1	1	3	1	1	1	1	4	1	1	1	1	1	1	1
4	0	0	0	1	0	0	2	3	0	0	2	0	4	0	0	0	0	0
5	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0
6	1	0	4	0	0	13	0	0	5	4	1	2	5	1	3	2	4	0
7	1	4	7	0	4	0	2	1	5	1	1	1	2	1	4	2	5	1
8	0	0	30	0	30	20	0	38	0	0	0	0	53.5	15	0	0	0	0
9	1	7	5	1	3	1	2	1	2	1	1	2	5	2	2	4	1	0
10	2	6	8	2	6	15	3	4	7	7	5	6	5	4	5	6	7	2
11	0.279	0	0.994	0.0461	0.483	6.789	0.241	0.214	0	0	1.059	0	0	0	0.692	1.672	1	0.185
12	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.05	0.01	0	0.01
13	10	1.6	1.6	10	0.8	1.6	0.8	1.6	0.8	1.6	0.8	1.6	1.6	1.6	1.6	0.8	0.8	0.8
14	0	0	24	0	0	5	25	0	0	4	5	0	0	0	1	10	40	26
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	2	1	1	4	1	4	1	1	1	1	1	1	1	0	2	1	2	1
2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	5	5	5	1
3	1	4	3	1	3	1	2	1	2	1	1	1	1	1	4	3	4	1
4	0	0	0	0	0	0	5	6	2	0	0	0	7	0	0	0	0	0
5	0	0	0	0	0	1	0	1	0	1	1	0	0	0	1	0	1	0
6	2	0	4	2	0	5	0	4	2	1	0	1	3	4	0	9	3	5
7	1	1	1	2	1	5	1	3	0	3	5	1	2	3	0	0	0	7
8	0	0	0	0	0	0	0	30	75	26.6	0	27.5	0	0	0	0	60	45
9	8	1	2	4	3	4	9	3	1	0	1	1	1	1	1	21	1	3
10	4	0	0	4	4	6	0	6	2	4	6	4	7	6	1	1	3	10
11	0	0.295	0.158	3.4666	0.172	1.143	0.067	0.226	0.4273	0.1019	0.439	0.281	0.528	0.815	0.455	2.19	1.3	0.937
12	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01
13	1.6	0.8	0.8	1.6	1.6	0.8	1.6	0.8	0.8	0.8	0.8	0.8	0.8	1.6	1.6	1.6	0.8	1.6
14	4	0	0	0	0	0	0	21	0	0	21	0	34	0	4	4	4	30
15	0	14	38	0	125	0	300	0	0	0	0	0	0	0	0	0	0	0

4. Results and Discussions

After the execution of FAFF algorithm for the above data, it generated 5-family set to 18-family set. Two sets out of all these sets are selected based on 'family index' value and presented here.

(a) 5-family set:

For c=-1.00, threshold T=0.314958, with family index=0.247613

Natural Seeds: 25 6 11 36 13

FAMILY	PARTS
1	1 4 20 21 23 25
2	6 34
3	11 33
4	3 5 7 8 9 10 16 17 18 24 26 28
5	2 12 13 14 15 19 22 27 35

(b) 13-family set:

For c=0.60, threshold T=0.561499, with family index=0.266979

Natural Seeds: 25 6 11 36 13 4 34 2 27 18 24 33 21

FAMILY	PARTS
1	25
2	6
3	11
4	3 17 26 29 36
5	13
6	1 4
7	34
8	2 12 14 15
9	8 27
10	7 18 31
11	9 16 22 24 32
12	19 33 35
13	5 10 20 21 23 28 30

After visual observation of parts, it is found that 8-family set is quite appropriate & better result. The same is also observed with the high family index value

5. Conclusions

In this paper, ***FAFF*** has been applied to an engineering industry to completely design the part families, based on similarity of part nominal and interval features. 36 parts and 15 features (5-nominal & 10-interval) are considered here for the case study.

The method has generated quite a number of sets of families, out of which 8-family set is found better family formation. This is also proved by the goodness criterion, family index.

Reference

1. *P.Venkata Chalapathi and Dr.YVSSSV.Prasada Rao, "Part FAmily Formation by Features (FAFF) in Group Technology", Udyog Pragati, The Journal of Practising Managers, NITIE, Mumbai, 2006.*