

Part Family Based Setup Time Optimization and Achieving Quick Setup Changeover Using Adaptive Fixturing

Ashish T.Patil¹, S.M.Pise², S.G.Bhatwadekar³, S.B.Sangale⁴

P. G. Student, Department of Production Engineering, K.I.T's College of Engineering, Kolhapur, India¹

Associate Professor, Department of Mechanical Engineering, K.I.T's College of Engineering, Kolhapur, India²

HOD, Department of Production Engineering, K.I.T's College of Engineering, Kolhapur, India³

Assistant Professor, Department of Production Engineering, K.I.T's College of Engineering, Kolhapur, India⁴

ABSTRACT: Manufacturing of discrete products having low volume and high varieties with complex part geometries many times result into longer manufacturing lead times. One of the major reasons for longer lead times is lengthy manufacturing setup times and setup changeover delays. Using adaptive fixturing one can reduce these setup times and achieve quick setup changeover. Adaptive fixturing uses same fixture for manufacturing new part from same part family with little modifications. Hence it greatly helps in set up time reduction. An adaptive fixture which can adapt all varieties of part family is developed for identified important part family at its lengthy manufacturing stages. Pre and post adaptive fixturing set up times are compared to ensure setup time optimization and to achieve quick setup changeover at lengthy manufacturing stages along with lead time and set up cost reduction.

KEY WORDS: Part family, setup time, quick setup changeover, adaptive fixturing

I. INTRODUCTION

Process industry based manufacturers supplying discrete manufacturing products have considerable pressure on them in terms of product delivery. Lead time shortening is prime objective in these industries. This paper deals with a case of heavy duty Rota (Rotary) Pumps (for Magma/ Masecute working fluid in sugar factory application) known as SM Pump used in process industries like sugar industry. Due to low volume high variety manufacturing in these industries along with complex product part geometries result into longer lead times. One of the prime reasons for these lengthy manufacturing lead times is longer manufacturing setup times.

Part family based adaptive fixturing is one of the pragmatic ways under these situations to reduce lengthy setup times. Part families i.e. groups of similar parts are formed in flexible manufacturing system in order to take advantage of part similarities in design and manufacture. One can find out important part family and its manufacturing stages responsible for lengthy set up times and develop adaptive fixture at these stages to reduce setup time and achieve quick setup changeover. Setup time, in general, can be defined as the time required to prepare the necessary resource (e.g. machines, people) to perform a task (e.g. job, operation). It is the elapsed time from when the last part of the current run is completed until the work centre starts running the first good piece of the next run. Setup cost is cost associated with set up time at given manufacturing stage. Two types of set up times are sequence independent and sequence dependent set up time. If setup time depends solely on the task to be processed, regardless of its preceding task, it is called a sequence independent. On the other hand, in the sequence dependent type, setup time depends on both task and its preceding task. [1] Quick set up change over is defined as the practice of reducing the time it takes to change a line or machine from running one product to next. [12]

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

Adaptive fixturing system is a type of flexible fixturing system which incorporates complicated fixture structures as well fixture bases and which takes a base of part families. One way to design an adaptive fixture is to identify an existing fixture that is designed to work with similar parts in the same family. Modify this fixture minimally to accommodate the requirements of the new part. [2] As same fixture is used for manufacturing new part from the same part family with little modification, it leads to setup time reduction and minimize set up change over delays.

II. LITERATURE REVIEW AND PROBLEM STATEMENT

Mervyn F. et al. have developed an adaptive machining fixture design system for automatically dealing with design changes. System senses a change made to the work piece model and automatically deals with the change for providing fixturing assembly relationship. Angelo Merlo et al. have developed a novel adaptive fixturing for thin walled aerospace parts. They Used actuator/sensor based clamping mechanisms while grinding thin walled components. T. Papastathis et al. have suggested a new fixture layout design methodology for a novel concept of adaptive machining fixtures with both actively controlled clamping forces and a dynamically adjustable layout. Edurne Olaiz et al. have developed a solution of adaptive fixturing system for smart and flexible positioning of large volume work pieces in the wind power sector by using electromechanical linear actuators along with ball screw mechanism to center the planet carrier. James Cunov et al. overcame the difficulty of manufacturing composites for aircraft components by developing adaptive manufacturing system with robotic fixture and precision motion machine with an integrated process head. Zunmin Geng's patent for adaptive fixturing system of thin walled shell/cylindrical components refers to a dynamic fixture adaptively fitting, supporting and achieving dynamic stability against cutting forces for thin walled components. Some of the issues from above literature review are:

Limited literature of part family based adaptive fixturing for component machining available from areas like automotive, aircraft and wind power sector, limited literature for part family based set up time optimization and achieving quick set up change over using adaptive fixturing for process industry based discrete manufacturing products, less work reported for adaptive fixturing with manual reconfiguration of fixture.

Based on the gaps identified from adaptive fixturing and other flexible fixturing systems literature review, problem is selected and stated in following way.

High variety low volume manufacturing environment and complex geometries of product part family result into lengthy manufacturing lead times and delay in product development. By considering these aspects, Lotus Engineering is facing a major problem of set up time optimization and achieving quick set up change over of part family of its major product Rota Pump during manufacturing. Based on this problem definition, objectives for the study are set as follows;

- a. To identify important Rota pump part family and its manufacturing stages responsible for longer set up time
- b. To optimize set up time and to achieve quick set up change over ensuring lead time reduction and set up cost reduction of selected part family at identified stages using adaptive fixturing.

III. IDENTIFICATION OF IMPORTANT ROTA PUMP PART FAMILY AND ITS MANUFACTURING STAGES WITH LONGER SETUP TIMES

As per methodology decided, data related to various bases for selecting important Rota Pump part family is collected and analyzed. By considering various bases like complexity in manufacturing stages and set up time, logistics involved, inventory level and weight of the component, important Rota pump part family is identified as "SM Pump Body" (comprising of 6", 9", 10" and 12" SM Pump Body and called as 6" Body, 9" Body, 10" Body and 12" Body). It is selected for developing adaptive fixturing for optimizing setup time and achieve quick setup changeover at manufacturing stages responsible for longer set up time.

Set up times for all manufacturing stages taking base of 9" SM Pump Body are recorded. Due to design and manufacturing similarities for SM Pump Body part family, inferences drawn from 9" Body will be directly applied to, 6", 10" and 12" Body. Set up times for various manufacturing stages of 9" Body are shown in table 1.

Table 1: 9” SM Pump Body manufacturing stages and their set up time

Sr. No.	Part Name	Manufacturing Stages and Set up Time (min.)						Total Set Up Time (min)
		1	2	3	4	5	6	
1	SM Pump Body	Marking	H.B.	HMC	H.B. SetUp1	H.B. SetUp2	Drilling	
	Set Up Time (Batch-5Nos.)	67	70	31	36	21	27	252

From table 2 first two stages i.e. marking and H.B. (Horizontal Boring machining stage for suction flange machining) are having more set up times. These stages are studied in detail and set up time details are found out. Marking (averaging of casting) is a process where component dimensions are transferred on casting by marking the dimensions from a fixed reference surface. Usually H.B. machine operator himself performs marking operation due to high skill requirement for it. During marking, H.B. machine remains idle. Therefore marking time is considered as set up time for H.B. machine. These markings are then aligned on H.B. machine and suction flange machining is carried out. Average set up times for 3 different observations while Body marking and machining Body suction flange on H.B. machine before adaptive averaging fixture with a batch of 5 numbers for each variety of SM Pump Body part family are recorded. Average set up time observations for change over from other part family to 1st Body, changeover from 1st Body to next same Body (Body 2-5) and average set up time for entire batch (Body 1-5) are taken. For 1st Body, it is sequence independent set up time (SIST) and from Body 2 to 5; it is sequence dependent set up time (SDST).

IV. DESIGN AND MANUFACTURING OF ADAPTIVE FIXTURE

As per research objectives, it was decided to develop an adaptive fixture for SM Pump Body marking and suction flange machining stages which can adapt entire SM Pump Body part family on common fixture. For that an adaptive averaging fixture will be developed at suction flange machining stage itself on H.B. machine which can perform both the functions i.e. averaging as well as setting SM Pump Body for suction flange machining stage.

It was decided to develop computer aided adaptive averaging fixture for 6”and 9” SM Pump Body first as per company’s decision. After manufacturing the fixture and appropriate machining results for 6”and 9” Body on it, 10” and 12” Body will be adapted on same fixture with required modifications. Various design softwares like DraftSight-2016 and Unigraphics-8 are used for development of adaptive averaging fixture.

While developing an averaging fixture which will adapt both 6” and 9’ SM Pump Body casting for suction flange machining, various design and manufacturing attributes are found out by aligning their bore centres as shown in figure 1. Based on these attributes, adaptive averaging fixture is developed.

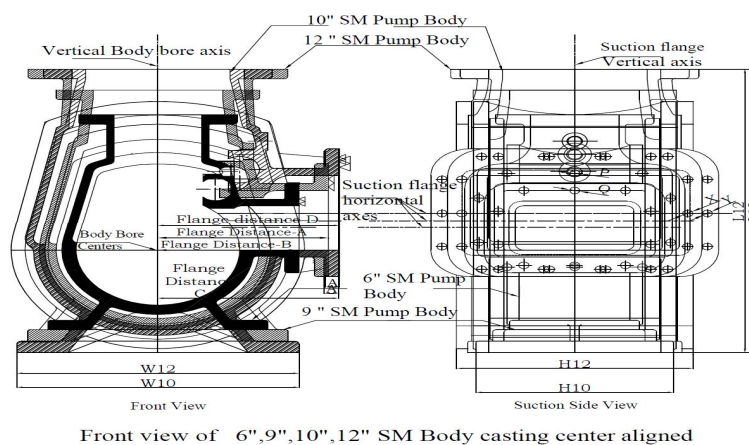


Figure 1: 6”, 9”, 10” and 12” SM Pump Body castings with Body bore centres aligned

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

i) While Body marking, averaging of Body is performed considering machining allowance and perpendicularity of machining surfaces and machining dimensions are transferred on Body to find out horizontal and vertical Body bore and flange centres. Finally flange machining distance from vertical Body bore axis is transferred. On H.B. machine, horizontal and vertical centres are aligned to perform flange machining. Same base is taken for developing adaptive averaging fixture and template base fixturing concept is used.

ii) In template base fixturing, templates of distinct profile of component are located on a fixture plate about a common reference point. Component is located by aligning its profile with that of template. Also some fixed datum surfaces and positions for deciding suction flange machining level and remaining axis positions are generated in relation to these template centres on fixtures. Once the component profile is aligned with that of profile of template, component centres are automatically generated in line with template centres. Thus component dimensions can be referenced from template centres and fixed datum surfaces.

iii) In SM Pump Body castings, parting line passes vertically through Body delivery flange and legs. It is found out that there is less casting variation in these areas. Therefore Body delivery flange and leg profiles are decided for creating templates. Centre height for templates is decided considering SM Pump Body cover side width and casting allowances.

iv) Templates will be mounted on fabricated brackets for 6"/9" SM Pump Body which are located coaxially using dowels opposite to each other on fixture plate in relation to common reference point(R).

vi) Body is decided to rest on four adjustable supports(S) along with side adjustable locators

v) After resting Body on adjustable supports on fixture plate, vertical fine adjustment of Body delivery flange and legs will be done using height adjustable supports (Screw Jack mechanism) by observing Body delivery flange and leg profile templates and supports bolts are locked after final adjustment. Horizontal fine adjustment will be done using bolt adjusted side locators. The fine adjustment should be such that both Body delivery flange and leg profile should nearly match or remain equal from all sides of profile templates as seen by naked eyes. Finally Body will be clamped.

vii) Tool setting block is used as setting block for deciding suction flange final machining level

viii) Suction flange centre setting block is used to find out horizontal suction flange axis. Vertical flange axis will be same as that of template axis.

Based on above design concept adaptive fixturing elements are manufactured and adaptive averaging fixture for 6" and 9" SM Pump Body is assembled using these elements. Adaptive averaging fixture image for 6" and 9" body is shown in figure 2.

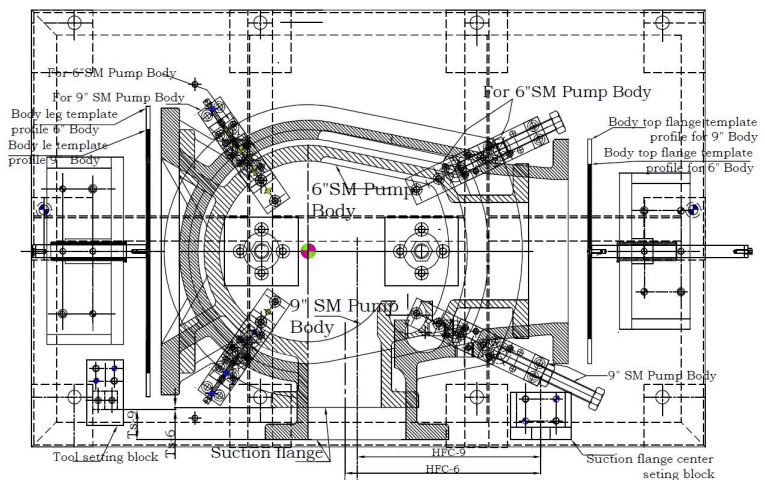


Figure 2: Adaptive averaging fixture for 6"/9" SM Pump Body

ix) In case of 10" and 12" SM Pump Body, side width is more than 6" and 9" SM Pump Body. As template centre height was fixed from top face of Fixture base plate while developing 6" and 9" SM Pump Body castings, support heights get reduced in both the cases. These heights are smaller as compared to support heights in 6" and 9" Body

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

cases. Therefore it is not possible to use screw jack mechanism in 10” and 12” SM Body cases. Therefore in these cases M20 bolt with lock nut are used. Accordingly different adjustable locators are manufactured.

xii) Body top flange and leg side dimensions are different for 10” and 12” SM Pump Body. Therefore different Body top flange and leg side profile templates will be required for both varieties of Body. Accordingly respective templates are manufactured.

With above two changes only, 10” and 12” Body can be adapted on averaging fixture as shown in figure 3.

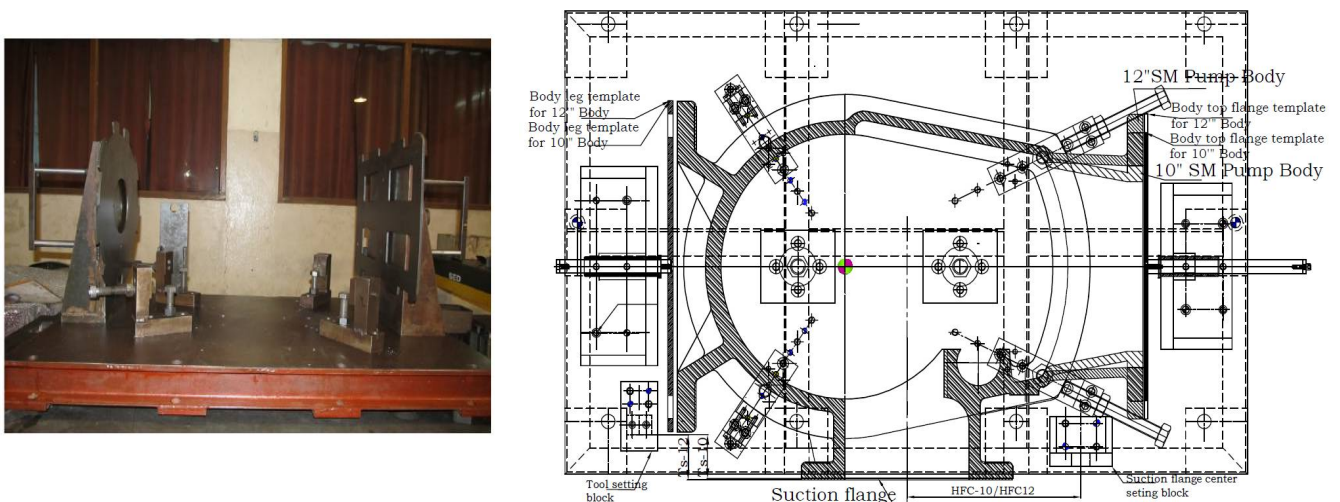


Figure 3: Adaptive averaging fixture for 10”/12” SM Pump Body

V. RESULTS AND DISCUSSIONS

Adaptive averaging fixture developed for SM Pump Body part family is implemented at suction flange machining stage on H.B. machine. It performs both the functions i.e. marking (averaging) as well as setting SM Pump Body for suction flange machining stage. Thus marking stage gets eliminated. Set up process is divided into various steps and post adaptive setup time observations are taken for these steps with a batch of 5 nos. of components for each variety of SM Pump Body part family while setting a Body on H.B.machine. Three different post adaptive fixturing set up time observations for each variety are recorded and average set up times are calculated. Comparison of pre and post adaptive fixturing average set up times for each variety of SM Pump Body part family is made. Comparison for various cases is shown below.

Table 2: Pre and post adaptive fixturing average marking time comparison for Body marking stage (Body 1 to5)

Sr. No.	Part Name	Avg. Marking Time (Body 1-5) Before Adaptive Fixturing (min)	Avg. Marking Time (Body 1-5) After Adaptive Fixturing (min)	Saving in Marking Time (A-B)(min.)	% Reduction in Marking Time
1	6" SM pump Body	59.2	0	59.2	100
2	9" SM pump Body	66.6	0	66.6	100
3	10" SM pump Body	71	0	71	100
4	12" SM pump Body	72.6	0	72.6	100

From table 2 it is seen that SM Pump Body marking stage gets completely eliminated due to adaptive averaging fixture and as marking time is considered under set up time on H.B. machine due to idleness of H.B. machine during marking stage, set up time saving on H.B. machine are 59.2 min., 66.6 min., 71 min., 72.6 min. respectively in case of 6”, 9”,

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

10", and 12" SM Pump Body. Lead time in each case will also be reduced by same amounts for supply of Body for SM Pump assembly.

Total annual saving in set up time at marking stage of SM Pump Body using data from table 2 is calculated as 673.5 hours.

Set up cost reduction per annum due to savings in SM Pump Body marking time (set up time on H.B.machine) at SM Pump Body marking stage, taking H.B. machine hourly rate as Rs.225/- is Rs.1,51,537.5/-.

Table 3: Pre and post adaptive fixturing average setup time at suction flange machining stage for 1st Body

Sr. No.	Part Name	Avg. Set up Time for 1st Body Before Adaptive Fixturing (SIST) (min)	Avg. Set up Time for 1st Body After Adaptive Fixturing (SIST) (min)	Saving in Set up Time (A-B)(min.)	% Reduction in Set up Time
1	6" SM pump Body	82	54.47	27.53	33.6
2	9" SM pump Body	88	57.73	30.27	34.4
3	10" SM pump Body	93	60.33	32.67	35.1
4	12" SM pump Body	98	61.27	36.73	37.5

From table 3 it is seen that, average set up time for change over from other part family to 1st SM Pump Body of 6", 9", 10", 12" variety get reduced by 33.6%, 34.4%, 35.1% and 37.5% respectively.

Table 4: Pre and post adaptive fixturing average setup time at suction flange machining stage for Body 2 to 5

Sr. No.	Part Name	Avg. Set-up Time (Body 2-5) Before Adaptive Fixturing (SDST) (min)	Avg. Set-up Time (Body 2-5) After Adaptive Fixturing (SDST) (min)	Saving in Set up Time (A-B)(min.)	% Reduction in Set up Time
1	6" SM pump Body	60	40.42	19.58	32.6
2	9" SM pump Body	66	41.15	24.85	37.7
3	10" SM pump Body	74	42.43	31.57	42.7
4	12" SM pump Body	77	43.28	33.72	43.8

From table 4 it is seen that, average set up time for change over from 1st SM Pump Body to next SM Pump Body (Body 2 to 5) of 6",9",10",12" variety get reduced by 32.6%,37.7%,42.7% and 43.8% respectively

Table 5: Pre and post adaptive fixturing average setup time comparison at suction flange machining stage on H.B. machine for Body 1 to 5

Sr. No.	Part Name	Avg. Set up Time (Body 1-5) Before Adaptive Fixturing (min)	Avg. Set up Time (Body 1-5) After Adaptive Fixturing (min)	Saving in Set up Time (A-B)(min.)	% Reduction in Set up Time
1	6" SM pump Body	64.4	43.23	21.17	32.9
2	9" SM pump Body	70.4	44.47	25.93	36.8
3	10" SM pump Body	77.8	46.01	31.79	40.86
4	12" SM pump Body	81.2	46.87	34.33	42.28

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

From table 5 it is seen that, average set up time for setting entire batch (Body 1 to 5) of 6", 9", 10" and 12" SM Pump Body variety get reduced by 32.9%, 36.8%, 40.86% and 42.28% respectively. Lead time in each case will also get reduced by same percentage for supply of Body for SM Pump assembly.

Total annual saving in set up time on H.B. machine at suction flange machining stage using data from table 5 is calculated as 283.07 hours.

Set up cost reduction per annum due to savings in set up time for SM Pump Body suction flange machining stage on H.B. machine, taking H.B. machine hourly rate is Rs. 63,690.75/-

VI. VERIFICATION OF EFFECTIVENESS OF ADAPTIVE FIXTURING FOR SET UP TIME OPTIMIZATION

To validate project objective of part family based set up time optimization and achieving quick set up change over using adaptive fixturing, it was decided to develop adaptive fixture at manufacturing stage of another important Rota Pumps part family and to see whether setup time is reduced and quick set up change over is achieved. This will verify effectiveness of adaptive fixturing in optimizing set up times of part families. As per company's decision, adaptive fixture for SM Pump part family "Flap" (comprising of 6", 9", 10" and 12" Flap) was developed on milling machine for its machining considering various design and manufacturing attributes for 6", 9", 10" and 12" Flap as shown in figure 4.

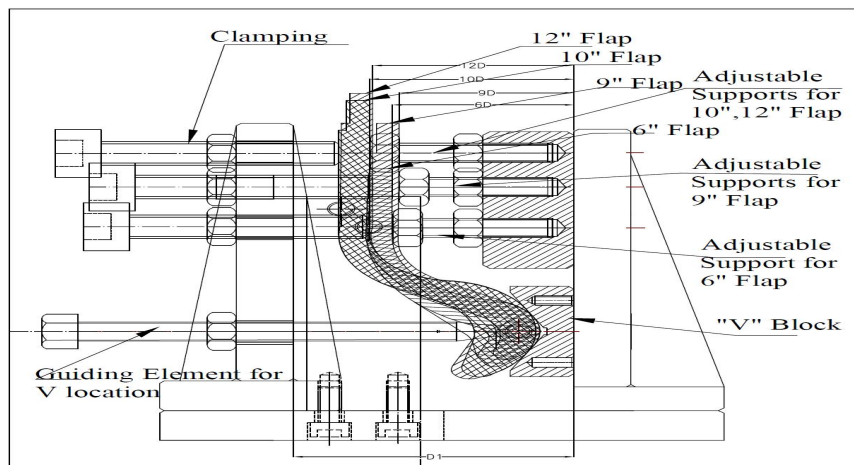


Figure 4: Flap part family adaptive fixture side view

Set up process is divided into various steps and post adaptive fixturing average setup times for these steps for 3 different observations with a batch of 5 nos. of Flap of each variety are taken. Various average setup time observations recorded are average set up time for changeover from other part family to Flap1, for change over from previous Flap to next same Flap (Flap 2 to 5) and average set up time for entire batch (Flap 1 to 5.)

Various findings from these observations are

- 1) Average set up time for change over from other part family to 1st 6", 9", 10" and 12" Flap variety get reduced by 52.8%, 54%, 57.6% and 61% respectively.
- 2) Average set up time for change over from 1st Flap to next Flap (Flap 2 to 5) of 6", 9", 10" and 12" variety get reduced by 30.4%, 36.7, 32.4% and 34% respectively.
- 3) Average set up time for setting entire batch (Flap 1 to 5) of 6", 9", 10" and 12" Flap variety get reduced by 39.7%, 43.4%, 42.8% and 45% respectively. Lead time in each case will also be reduced by same percentage for supply of Flap for SM Pump assembly.
- 4) Total annual saving in set up time on milling machine at Flap milling stage is calculated as 254.75 hours.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

- 5) Set up cost reduction per annum due to savings in set up time at SM Pump Flap milling stage on milling machine, taking milling machine hourly rate as Rs.100/- is Rs. 25,475/-.

VII. CONCLUSIONS

Using adaptive averaging fixture for SM Pump Body part family, Body marking time is reduced to zero. Setup time at suction flange machining stage for SM Pump Body part family is reduced and purpose of quick set up change over from other part family to SM Pump Body and from SM Pump Body to next SM Pump Body is accomplished. Effectiveness of adaptive fixturing is verified with reduction in set up time while machining SM Pump Flap part family using adaptive fixture and achieving quick setup change over from other part family to SM Pump Flap and from SM Pump Flap to next SM Pump Flap. Lead time for supply of components and setup cost associated with these stages also reduced. Dependence on skill of the H.B. machine operator is reduced. With little training, even a semiskilled operator can also set SM Pump Body for machining using adaptive fixturing

REFERENCES

1. Ali Allahverdi, H.M. Soroush, The significance of reducing setup times/setup costs, European Journal of Operational Research, 187, pp.978–984, 2008
2. Yiming Rong, Samuel H.Huang, Zhikun Hou, A Book on Advanced Computer -Aided Fixture Design, Elsevier Academic Press, 2005
3. Fathianathan Mervyn, Senthil. A, Nee Kumar A.Y.C., An Adaptive Machining Fixture Design System For Automatically Dealing With Design Changes, Journal of Computing and Information Science in Engineering, Vol.7, pp259-268, 2007
4. Angelo Merlo, Donato Ricciardi, Edoado Salvi, Novel Adaptive Fixturing For Thin Walled Aerospace Parts, Trends in aerospace manufacturing International conference, IOP Conf. Series: Materials Science and Engineering 26, 2011.
5. T. Papastathis, O. Bakker, S. Ratchev, A. Popov, Design Methodology For Mechatronic Active Fixtures With Movable Clamps, Sciverse Science Direct, Procedia, CIRP,3 pp.323-328, 2012
6. Edurne Olaize, Junajo Zulaika, Fernando Ueiga, Milderred Purto and and A.Gorrotxategi, Adaptive Fixturing System For Smart And Flexible Positioning of Large Volume Work Piece In The Wind Power Sector, Science Direct, Procedia CIRP21,pp.183-188,2014
7. Cunov. J, Habernann. C, Adaptive Manufacturing System, SAE International Journal of Aerospace.7(2), pp.322-327,2014
8. Zunmin Geng, Adaptive Design Of Fixture For Thin-Walled Shell/Cylindrical Components, Patent Publication Number US20140283368 A1, Publication date Sep 25, 2014.
9. Darius Ceglarek, Multivariate Analysis And Evaluation Of Adaptive Sheet Metal Assembly Systems, CIRP Annals, Manufacturing Technology, Vol.47,pp.17-22,1998
10. Louise Izquierdo, S. Jack Hu, Hao Du, Ran Jin, Haeseongjec and Jianjun Sh, Robust Fixture Layout Design for a Product family Assembled in a Multistages Reconfigurable Line, Journal Of Manufacturing Science Eng Vol.131(4),pp.041008-1-9,2009
11. J. Padayacheel and G. Bright, The Design Of Reconfigurable Assembly Stations For High Variety And Mass Customization Manufacturing, South African Journal of Industrial Engineering Vol. 24(3), pp. 43-57, 2013
12. <http://www.vorne.com/learning-center/smed-quick-chnageover.html>,Dated 09/08/ 2015