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Design Optimisation and Manufacturing Analysis of Transmission Fork of Heavy Motor Vehicles

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Abstract: During the process of Milling for v cut Slot minor Cracks are generated in fork Surface, which during induction hardening process converts in to deep cracks and can only be detected during the non-destructive testing like MPI (Magnetic Particle Inspection). This leads to higher rejection ratio and incur financial and material losses. The existing design of fork is heavy and not compact which leads to problems during assembly and leads to bending in rails. This necessitates a new design of fork which is compact and light weight. The second design is manufactured without v slot using standard manufacturing techniques which includes process flow diagrams and PFMEA.
Keywords: PFMEA, PFD, MPI Testing

I. TRANSMISSION FORK

The fork of the car is one of the key parts of the car speed shifting system playing an important role in shifting the speed and changing the direction. The fork could move the ring gear of synchronizer to separate and unite thus the speed shifting is achieved. As a part of the car the fork has a bearing on the safety of the car and person. The clear speed gear and the smooth transition have always been the objective of the transmission control facility design and important index for evaluation of good transmission. The ingenious and flexible control facility could not only improve the comprehensive function of the transmission but also promote the comfortable feeling of driving and riding.

II. OBJECTIVE

This project studies the inspection methods carried out in manufacturing of Transmission Fork. The inspection methods are intended to reduce defect rates in finished products and improve quality of product. The inspection methods involved are CMM testing, MPI testing, Induction Hardening, material testing, hardness testing.

III. LITERATURE REVIEW

Dogan [1] has done critical work to reduce the movements and vibrations of the transmission. The torsional vibrations of the gears cause abrupt and rattling movements, these noises are troublesome. For the exploratory examinations, the transmission parameters have been modified to reduce the effects of vibration and blast noise.

Wang and Yang [2] studied the non-linearity of dental optics in the rigging elements. Adaptive force and frictional forces were used for digital reproduction light. In this study, the basic parameters were distinguished and the clutter, the branch with sliding friction taken into account.

Abouel-Seoud and Abdallah [3] used the method of investigation of the vibration reaction for the systematic search of the transmission frame of the vehicles. You have done scientific examinations and tests on a vehicle transmission frame. Using physical properties, they calculated the effectiveness of the radiation.

Vandi and Ravaglioli [4] show in this article the use of a fractional transmission model to complement a current vehicle dynamics model. The connection with and the wonders separated from the handle were examined.

Nacib and Sakhara [5] reflected on the huge helicopter transmission. In order to counter the separation and misdeeds of helicopters, the identification of blame is crucial. Cepstrum's scope review and investigation strategy is used to distinguish damaged material. The Fourier study is used for scientific results.

IV. METHODOLOGY

The manufacturing process of transmission fork involved following steps:

1) *Arrangement of Raw Material:* Raw material of Fork received from an approved forger is SAE 1541.Forging Testing will be conducted on Fork for knowing the specifications of Fork. In this fork is also tested in lab for chemical composition test
2) *Test of Raw Material:* It is carried out on receipt of raw material at works. Also, samples will be taken from each heat and given to NABL Lab for Chemical Analysis which will be normally done for all grade of steel. Raw material will be issued for

production only after confirming the Chemical specifications from NABL Lab and quenched hardness.

3) *Reduction Ratio Test:* Forging reduction is generally considered to be the amount of cross-sectional reduction taking place during drawing out of a bar or billet. The original cross-section divided by the final cross-section is the forging ratio (say 3:1). There is an equivalent reduction on upsetting for forgings being upset during forging (gear blanks, for example). In this case, the upset ratio of beginning billet length over final height is the upset ratio. This is similar in total reduction to the bar reduction.
4) *Spark Testing:* Spark testing is a method of determining the general classification of non-ferrous materials. It normally entails taking a piece of metal, usually scrap, and applying it to a grinding wheel in order to observe the sparks emitted. These sparks can be compared to a Figure or to sparks from a known test sample to determine the classification.
5) *Machining of Fork:* Machining of fork is firstly conducted on SPM milling machine In SPM milling part Is Rested horizontally, Fork Ribs rested on Bed and Milling will be conducted on both top of Fork. After Milling, Boring Operation is conducted on Fork. Vertical Milling Operation on Fork will be conducted with the help of Fork Fixture in Which fork horizontally rested on fixture, Hydraulic Clamping will be done on Fork Ribs. Then Pad Milling operation will be conducted on Fork. In this Pad Milling Operation Curve on Pads Also given.
6) *Induction Hardening:* Induction hardening is a form of surface hardening in which a metal part is induction-heated and then quenched. The quenched metal undergoes a martensitic transformation, increasing the hardness and brittleness of the part. Induction hardening is used to selectively harden areas of a part or assembly without affecting the properties of the part as a whole.
7) *Tampering:* Tempering the process step of tempering is applied post to the hardening process for almost all critical parts or parts subject to high stresses. The hardening process creates a stressed matrix which, although resulting in a high hardness due to C-atoms in solution, also leads to a high Microstructure distribution at the tapering out of the hardening zone.

V. RESULTS AND DISCUSSION

A procedure flow diagram (PFD) is an outline that is normally utilized in procedure building to demonstrate the general stream of procedures. PFD demonstrates the most essential generation procedure of a segment. The stream chart of the howling procedure demonstrates the fork spoken to by the generation procedure as shown in figure 2.

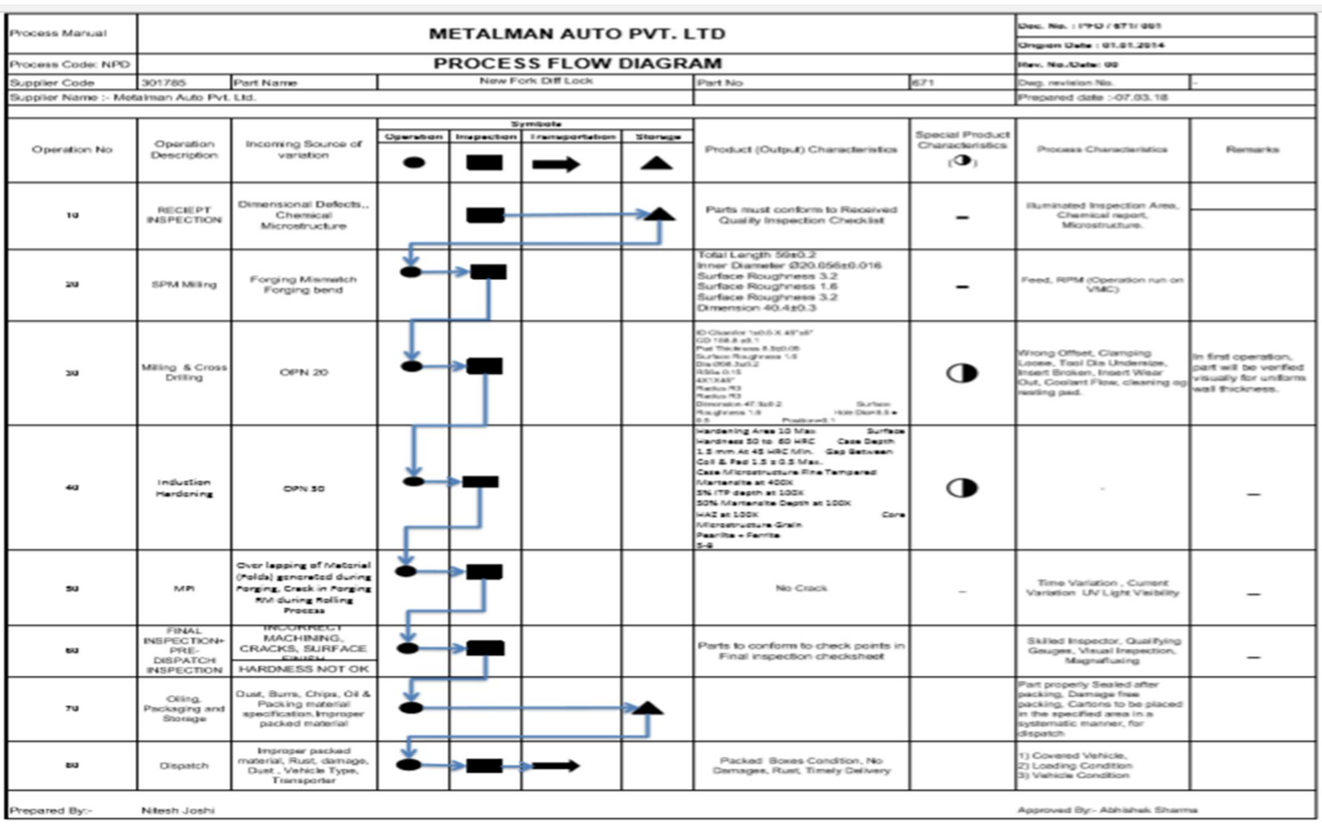

Fig. 2 Process Flow Diagram of 671 Fork

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The analysis of the effective modes of process error is based on different parameters to determine the number of risk priorities obtained by the severity of the specifications, the appearance of errors and the detection of dimensions in different operations as shown in the Figure 3.

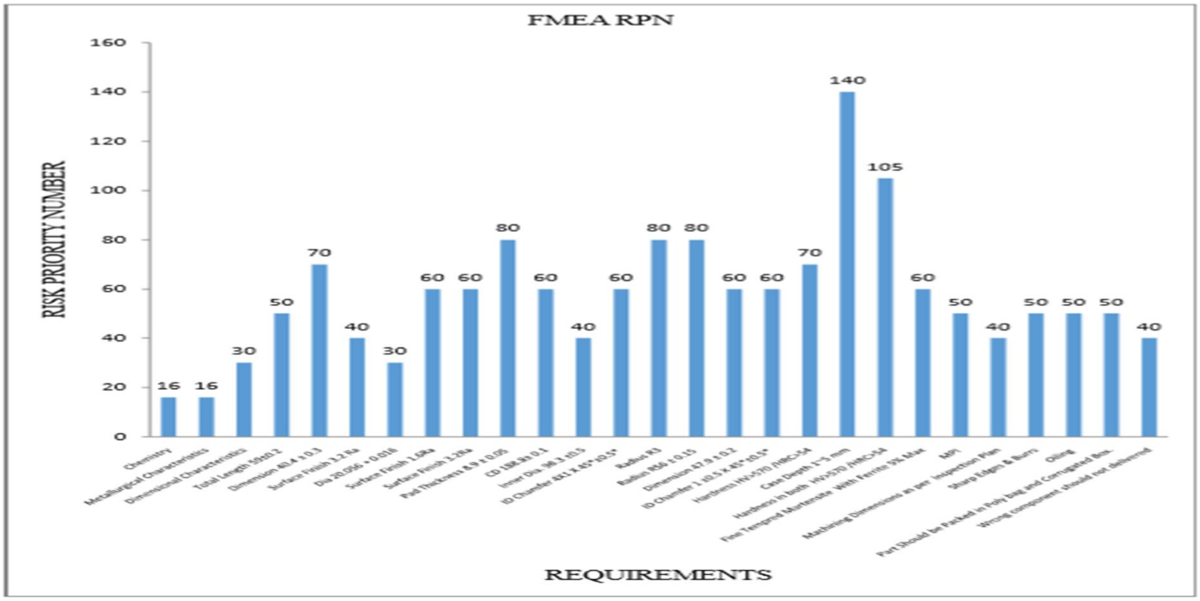

Fig. 3 Process Flow Diagram of 671 Fork

Risk priority number = severity x occurrence x detection

As should be obvious in the chart between the necessities and the quantity of hazard needs, the most extreme hazard in the fork is to keep up the profundity of the crate of 125 mm and accomplish the hardness in the acceptance procedure.

METALMAN	METALMAN AUTO PVT. LTD. Forging Report	Form No.	MAPL/F/PROD/51
		Issue:	01
		Sheet No.	1/1

Report No.	3023	Date	20/01/2018
Part Name.	Fork Diff. Lock	Raw Material	SAE 1541
Part No.	671	Raw Material Used	SAE 1541
Material TC	Recieved	Heat No./Heat code	17B2370/17L11
Suppler Name	Harpreet Forgings	Qty	100 Nos

Chemistry (as per Std.) (Test Method – ASTM E415)

Composition	%C	%Mn	%Si	%P	%S	%Cu	%Cr	%Mo	%Ni	%Cr+Mo+Ni	%Ca
Specified Min.	0.36	1.35	0.15	-	-	-	-	-	-	-	-
Specified Max.	0.44	1.65	0.35	0.040	0.040	0.30	0.20	0.06	0.12	0.25	
Obs. Value T.C	0.40	1.46	0.23	0.020	0.021	0.006	0.090	0.001	0.005	0.096	-
Inhouse Spectro	0.38	1.36	0.27	0.019	0.010	0.004	0.18	0.050	0.008	0.23	0.09

Inclusion Rating at 100X (as per Std.)

Type	(A) Sulphide		(B) Alumina		(C) Silicate		(D) Oxide	
	Thin	Heavy (Thik)	Thin	Heavy (Thik)	Thin	Heavy (Thik)	Thin	Heavy (Thik)
Specified	4	3	4	3	3	2	2	2
Observed Supplier T.C	1.5	-	1.0	-	1.0	-	1.5	-

Metallographic Observation:

Test	Specification	Observation	Remark
Core Microstructure	Pearlite + Ferrite	Pearlite / Ferrite	OK
Grain	5 – 8	7	OK
Macro Test (T.C)	C2, R2, S2 Max	C2, R2, S2	OK
Hardness	241 BHN Max	179 - 183 BHN	OK

Remark: - OK

Checked By: Jimmy **Approved By: S.G Deshmukhe**

Fig. 4 Forging report of 671 Fork

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As indicated by the test report of the distortion material, it gave the idea that the essential small scale organizing necessity, to be specific the blend of grains and ferrite, is seen in the tests dependent on the span of the required particles. 183 BHN was found as demonstrated in the past report. As appeared in Figure 4

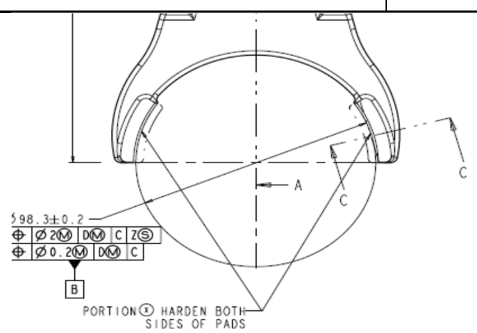
METALMAN	***METALMAN AUTO PVT. LTD.*** **Material Test Report**	**Form No.**	**MAPL/F/PROD/51**
Report No.	***18030018***	Date	15/04/2018
Part Name.	***FORK, DIFF LOCK SHIFTER***	Raw Material	SAE 1541
Part No./ Rev. No.	***R140671(218384RE/B)20010302***	Raw Material Used	SAE 1541
Material TC	***Received Ok***	Heat No.	B239(5567)
Heat Treatment Process	***Induction Hard. & Temp. (HT30T)***	Quantity	10 Nos.
Induction Hardening Batch, done & date	***K22C18***	Chemical Composition Report No. & Date	
	14/04/2018		
Component Sketch			

Fig. 5: Material test report of 671 Fork

In the induction hardening model we performed the operation in position x as shown in the report, with an energy consumption of 18% after 2 seconds and a lifting speed of 150 mm with a cooling speed of 8 seconds. The depth of the box on a road is 2.4 mm. and b is 2.3 mm based on the required requirements. The microstructure is a well-designed martensis, a microstructure of ferrite core and a perlite with a grain size of 7 mm and a rigidity between 56 and 57 hc as shown in Figure 6 and Figure 7.

Machine no.	**2**	**KW**	**100 KW**	
Location	**X**	**Location**	**X**	**OK**
Power (kW)%	18 %	Rotation	no	
Start Heating Time	After2 secs	Frequency KHZ	30 kHz	
Heat Dwell Time	1.65 Sec	Polymer% (Without factor)	2%	
Scan Speed (Feed)	150 mm/min	Total Cycle Time	14 Sec	
Total Heating Time	2 sec	Quenching Bath Temp.	27 °C	
Total Quenching Time	8 secs	Tempering Temp.	160°C @ 90 min.	

Fig. 6: Pattern testing report

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<table>
<tr><td>Test</td><td>Specification</td><td colspan="2">Observation</td><td>Remark</td></tr>
<tr><td rowspan="5">Case Microstructure</td><td>Fine Tempered Martensite at 400X</td><td colspan="2">Fine Tempered Martensite</td><td>OK</td></tr>
<tr><td rowspan="2">5% ITP depth at 100X</td><td>Paid 1</td><td>Paid 2</td><td rowspan="2">OK</td></tr>
<tr><td>A- 1.3, B- 1.2 mm</td><td>A-1.4, B-1.3 mm</td></tr>
<tr><td>50 % Martensite Depth at 100X</td><td>A -1.9, B – 1.8 mm</td><td>A-1.8, B- 1.8 mm</td><td>OK</td></tr>
<tr><td>HAZ at 100X</td><td>A-2.5, B – 2.3 mm</td><td>A -2.5, B -2.3 mm</td><td>OK</td></tr>
<tr><td>Core Microstructure</td><td>Pearlite + Ferrite</td><td colspan="2">Ferrite / Pearlite</td><td>OK</td></tr>
<tr><td>Grain</td><td>5 – 8</td><td colspan="2">7</td><td>OK</td></tr>
</table>

Case Depth @ Pad 1 Loc.

<table>
<tr><td>Dist. In mm</td><td rowspan="2">A</td><td>0.1</td><td>1.0</td><td>2.0</td><td>2.4</td><td></td><td></td></tr>
<tr><td>Hard. In HV1</td><td>630</td><td>630</td><td>584</td><td>395</td><td></td><td></td></tr>
<tr><td>Dist. In mm</td><td rowspan="2">B</td><td>0.1</td><td>1.0</td><td>2.0</td><td>2.3</td><td></td><td></td></tr>
<tr><td>Hard. In HV1</td><td>623</td><td>627</td><td>500</td><td>260</td><td></td><td></td></tr>
</table>

Case Depth @ Pad 2 Loc.

<table>
<tr><td>Dist. In mm</td><td rowspan="2">A</td><td>0.1</td><td>1.0</td><td>2.0</td><td>2.5</td><td></td><td></td></tr>
<tr><td>Hard. In HV1</td><td>613</td><td>652</td><td>605</td><td>304</td><td></td><td></td></tr>
<tr><td>Dist. In mm</td><td rowspan="2">B</td><td>0.1</td><td>1.0</td><td>2.0</td><td>2.2</td><td></td><td></td></tr>
<tr><td>Hard. In HV1</td><td>664</td><td>675</td><td>522</td><td>271</td><td></td><td></td></tr>
</table>

<table>
<tr><td rowspan="4">Pattern Photo</td><td rowspan="2"></td><td>1</td><td>4.60 mm</td><td rowspan="4"></td><td>L1</td><td>5.95 mm</td></tr>
<tr><td>2</td><td>5.25 mm</td><td>L2</td><td>5.81 mm</td></tr>
<tr><td rowspan="2">
4 3</td><td>3</td><td>2.81 mm</td><td>L3</td><td>5.97 mm</td></tr>
<tr><td>4</td><td>8.15 mm</td><td>L4</td><td>5.31 mm</td></tr>
<tr><td colspan="7">Pad 2
Remark:

Checked By: Jimmy Ashok Mansare — Approved By:</td></tr>
</table>

Fig. 7 Case depth testing report

MPI testing is a kind of non-destructive test to detect cracks with a coil of approximately 1250 to 1400 amps with an oil concentration of 3.15- and 0.3-ml. Check the cracks that generate a magnetic field in the fork, apply the oil flow and then detect in the presence of UV rays. On the one hand, the magnetic field is generated and, on the other hand, the stress control generated by the ultraviolet rays to create cracks in the part during the process. 100% of the parts must be checked in MPI to eliminate the cause of the field failure in the vehicle function. In this process, the following parameters should be maintained as shown in fig 8.

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METALMAN	M.P.I.Check Sheet	Format No.:- MAPL/F/QC/110
		Rev No. 00
		Issue Date:- 10.03.2017

Process Parameter details:-	1..Machine No. 01	3. Demagnetize :- Working	4. Defective Sample:-Checked	7. Circular coil:-Working
	2. Oil flow:- Yes	4. Bulb Intensitiy:- ok	2. Pie Testing:-Checked	8. L Coil :- Working
	9.Oil level:-Yes	10.Calibration Status:- Yes	11.No. of Strokes :- 1	12.Type of Magnatized:- Combined
	13. Coil knob setting:- 2+2High	14. L. Knob Setting:- 3	15.Copper bush avability:- N.A	OK

Part details		Part Length:- 212 mm	Operator Name:
	Part Name: Fork	Part Grade :- SAE-1541	sawan
	Part Max. Dia :- 42 mm	Part Condition:- Forged, Bright bar:- Forged	Date:- 16.04.18
	Induction Batch No.- K28C18	Heat No.- THE FORGING	Lot Qty.- 10 NOS

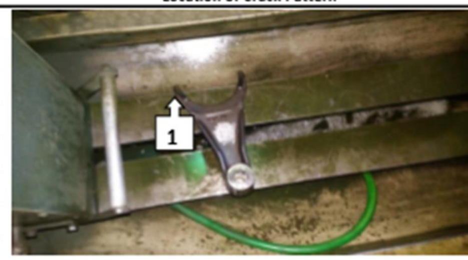
Setup

Required Current:-	Circular Coil:- 1250 ± 100	L. Coil :- 3.00 Kat Min.	Oil Concentrate :- 0.2~0.4 ml/ltr
Actual :-	1400 AMP	3.15 KAT	0.3 ml

Sl No.	Time	Quantity Checked	OK	NOT OK	Demagnetize
1	8:00 PM	5	5	0	Yes
2	9:00 PM	5	5	0	Yes
Total		10	10	0	

Loading pattern photograph

Location of Crack Pattern



Remarks:-

Checked By:-Mr. Akshay   Approved By:-Mr ASHOK MANEARE

Fig. 8 M.P.I testing report

In the test section of the test machine of the test bench to control the adjacent dimensions, which is the required position of the indirect hole and the CD tent, which is the main dimension of the set. In CMM, the test was perpendicular and the parallelism and angle of the hole crossed within tolerance and strict specifications as can be seen in Figure 9.

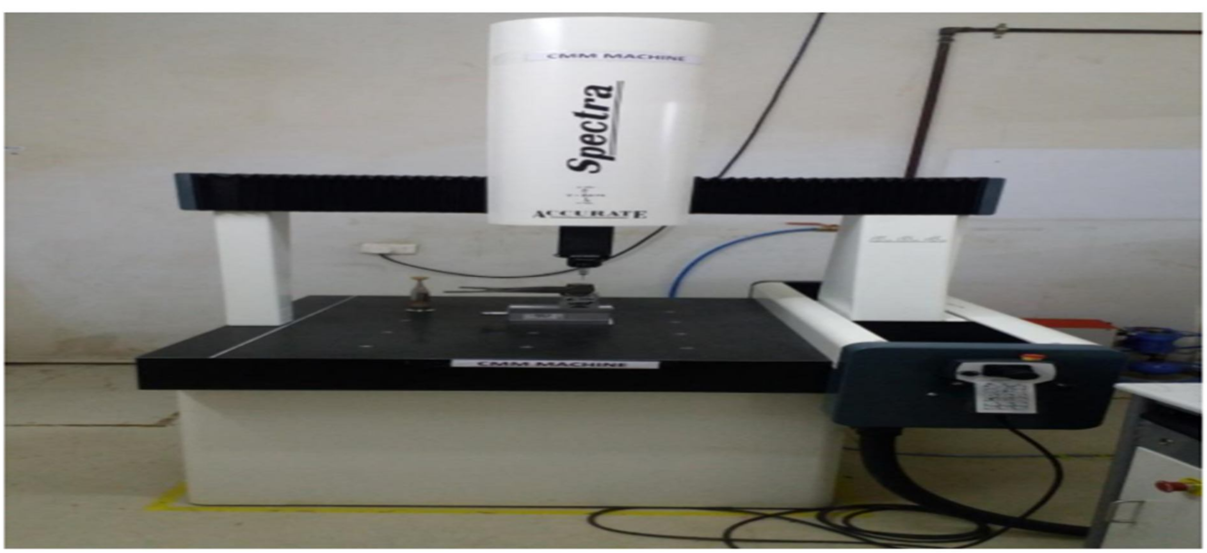


Figure 9: CMM testing machine

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METALMAN AUTO PVT. LTD.

Customer Name:	VECV	Date:	14-04-2018
Part Name:	Fork	Time:	17:05:19
Inspected By:	Pradeep Kumar Jha	Part No. :	R140671
Approved By:	Ashok Mansare	CMM INSPECTION REPORT	

	A	N	D/B	LT	UT / T	OOT
POSITION_OF_HOLE_20.056 [CYL_2][POS]						
Pos	0.1612		0.0000		0.2000	
CD_188.80 [CYL_1 - CYL_2][DISTB]						
Dst	188.8806	188.8000	0.0806	-0.1500	0.1500	
PARPENDICULARITY_0.1 [CYL_2][PERP]						
Per	0.0226		0.0000		0.1000	
ANGLE_60 [PLA_6 - PLA_7][ANGLB]						
Dst	60.2765	60.0000	0.2765	-2.0000	2.0000	
ANGLE_39.9 [PLA_8 - LIN_1][ANGLB]						
Dst	39.9524	39.9000	0.0524	-0.5000	0.5000	
ANGLE_29.9 [PLA_12 - LIN_2][ANGLB]						
Dst	29.8925	29.9000	-0.0075	-0.5000	0.5000	
ANGULARITY_0.6 [PLA_8][ANGLR]						
Ang	0.0274		0.0000		0.6000	
CYL_1[CYLNDR/INNER]						
Dia	98.3805	98.3805	0.0000	-0.1500	0.1500	

Figure 10: CMM testing report

VI. CONCLUSION

The test unit of the drive unit runs on the fork using the obtained programs that show that the fork without V-groove and U-groove work better than the fork with U and V grooves. They have helped to reduce weight. Along with this, the rejection rates that were higher in the notched forks are drastically reduced. Therefore, the elimination of the grooves has helped to reduce the weight and a great compactness is obtained that leads to a better adaptation of the interference in the assembly line and to decrease the waste speeds during manufacturing.

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