iJRASET

International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 Issue: V Month of publication: May 2019

DOI: <https://doi.org/10.22214/ijraset.2019.5089>

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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) **Tempering:** 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

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 AUTO PVT. LTD.		Form No.	MAPL/F/PROD/51								
Forging Report		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	Reviewed	Heat No./Heat code	17B2370/17L11								
Supplier Name	Harpreet Forgings	Qty	100 Nos								
Chemistry (as per Std.) (Test Method – ASTM E415)											
Composition	%C	%Mn	%Si	%P	%S	%Cu	%Cr	%Mo	%Ni	%C+Mn+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 (Thick)	Thin	Heavy (Thick)	Thin	Heavy (Thick)	Thin	Heavy (Thick)			
Specified	4	3	4	3	3	2	2	2			
Observed	1.5	-	1.0	-	1.0	-	1.5	-			
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

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

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 martensite, 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.	

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

Case Depth @ Pad 1 Loc.

Dist. In mm	A	0.1	1.0	2.0	2.4		
Hard. In HV1		630	630	584	395		
Dist. In mm	B	0.1	1.0	2.0	2.3		
Hard. In HV1		623	627	500	260		

Case Depth @ Pad 2 Loc.

Dist. In mm	A	0.1	1.0	2.0	2.5		
Hard. In HV1		613	652	605	304		
Dist. In mm	B	0.1	1.0	2.0	2.2		
Hard. In HV1		664	675	522	271		

Pattern Photo			1	4.60 mm			L1	5.95 mm
			2	5.25 mm			L2	5.81 mm
	3	2.81 mm			L3	5.97 mm
			4	8.15 mm			L4	5.31 mm

Remark:

4

3

Pad 2

Checked By: Jimmy
Ashok Mansare

Approved By:

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.

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
	2. Oil flow:- Yes	4. Bulb Intensity:- ok	2. Pie Testing:-Checked
	9.Oil level:-Yes	10.Calibration Status:- Yes	11.No. of Strokes :- 1
	13. Coil knob setting:- 2+2High	14. L. Knob Setting:- 3	15.Copper bush availability:- N.A
Part details	Part Length:- 212 mm		Operator Name:
	Part Name: Fork		Part Grade :- SAE-1541
	Part Max. Dia :- 42 mm		Part Condition:- Forged, Bright bar:- Forged
	Induction Batch No.- K28C18		Heat No.- THE FORGING
Setup	Required Current:-	Circular Coil:- 1250 ± 100	L. Coil :- 3.00 Kat Min.
	Actual :-	1400 AMP	3.15 KAT
	Oil Concentrate :- 0.2~0.4 ml/ltr		0.3 ml
	SI No.	Time	Quantity
			Checked OK NOT OK
			Demagnetize
	1	8:00 PM	5 5 0
	2	9:00 PM	5 5 0
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

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	L / T	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]						
Dist	188.8806	188.8000	0.0806	-0.1500	0.1500		
	PERPENDICULARITY_0.1 [CYL_2][PERP]						
Per	0.0226		0.0000		0.1000		
	ANGLE_60 [PLA_6 - PLA_7][ANGLE]						
Dist	60.2765	60.0000	0.2765	-2.0000	2.0000		
	ANGLE_39.9 [PLA_8 - LIN_1][ANGLE]						
Dist	39.9524	39.9000	0.0524	-0.5000	0.5000		
	ANGLE_29.9 [PLA_12 - LIN_2][ANGLE]						
Dist	29.8925	29.9000	-0.0075	-0.5000	0.5000		
	ANGULARITY_0.6 [PLA_8][ANGLR]						
Ans	0.0274		0.0000		0.6000		
	CYL_1 [CYLINDER 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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