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Process Improvement in the Manufacturing of Engine Valve

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***Abstract*—*An I.C. Engine contains generally two types of valves i.e. inlet valve and exhaust valve. These valves are again classified into two types. One is mono metal and the other one is bi-metal. Mono metal valve is made by using only one metal. Bi-metal valve is made by two types of metals. Any valve is divided into two portions, one is head portion and the other one is stem portion. In bi-metal valve head and stem portion are made of different metals. Two different types of metal bars are joining by the process of friction welding. Friction welding is the process of joining two solid pieces by welding, in which heat is generated by friction between stationary and rotating work piece. After friction welding next operations are bar grinding and forging.*

The above process is called as Pin-Pin friction welding process. This paper aim is to convert Pin-Pin friction welding process into Head to pin friction welding. In this route forging is done only for head bar and it is joining with stem bar by the friction welding process.

***Keywords—pin-pin friction, Head – pin friction*.**

I. INTRODUCTION

The REVL isone of the Units ofRane Group.The REVL is Deming award winning company engaged in manufacturing Valves for Internal Combustion Engines for automobile manufacturers in India and it also exports its products to Germany, Italy, UK, USA, Iran and Sri Lanka, Australia etc. (An ISO 9001: 2000, ISO 14001 accredited company with annual company turnover of Rupees 270 crores,).

1. About Valves:

Engine Valve is one of the main parts which are used in all IC Engines. Each cylinder in the engine has one inlet and one exhaust valve. Now a days engine are designed with multi valves viz., two inlet and one exhaust or Two inlet and Two exhaust valves which prevents air pollution and improves engine efficiency.

1.1. Function of Inlet Valve: The inlet which operates by the action of Tappet movement, allows air and fuel mixture into the cylinder.

1.2.Function of Exhaust valve: The exhaust valve allows burnt gases to escape from the cylinder to atmosphere.

1.3.Valve Efficiency: Depends on the following characteristics like Hardness, Face roundness and sliding properties capable to withstand high temperature etc.

As compared to inlet, exhaust valve operates at high temperature as exhaust gases (around 800 Deg C) escape through it. As it resulting in early ways and gets corrosion, austenitic steel is used for manufacture of exhaust valve and martens tic steel is used for manufacture of inlet valve.

The manufacturing process involves upset and forging, heat treatment and machining (turning and grinding) and special processes like TIG welding, Projection Welding, PTA Welding, Friction Welding, Induction Hardening and Nitriding.

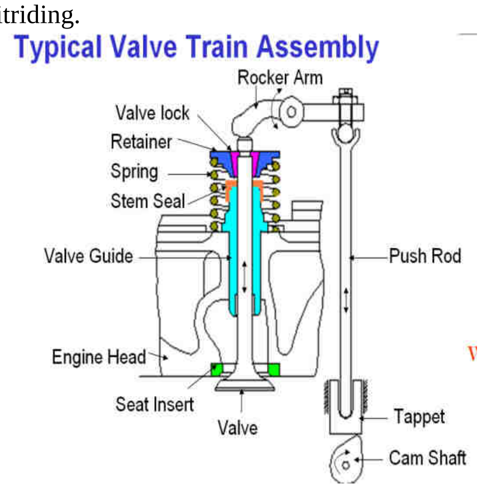

Fig.1: Valve Train Assembly

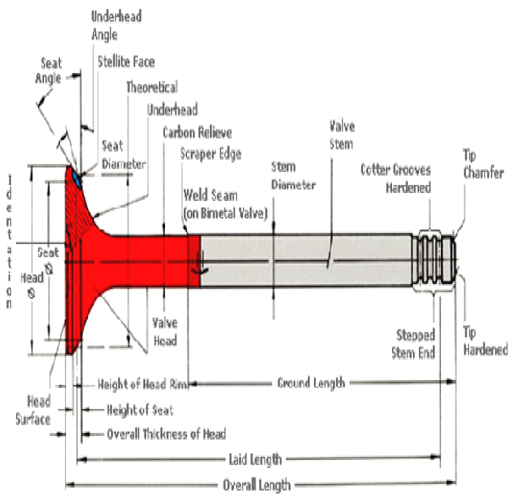

Fig.1.1: Valve Diemensions

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1.4. Working Requirements for Valves

1. Inlet Valve
   a) Allow incoming charge into the engine
   b) Seal the port without leak for remaining period
   c) Resistance to wear at the mating surfaces
   d) Good sliding surface for seizure resistance
2. Exhaust Valve
   a) Allow gases go out of the engine
   b) Seal the port without leak for remaining period
   c) Strength to with stand high temperatures
   d) Resistance to wear at the mating surfaces
   e) Good sliding surface for seizure resistance

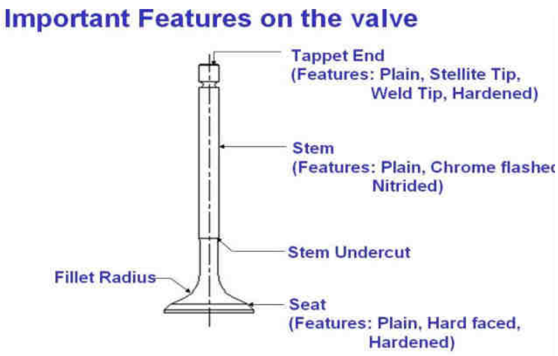

Fig.1.2: Features of Valve

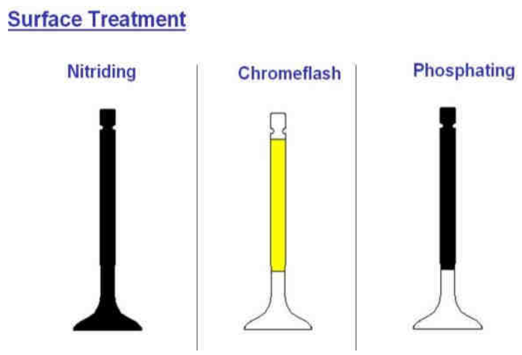

Fig.1.3: Surface Treatment Of Valve

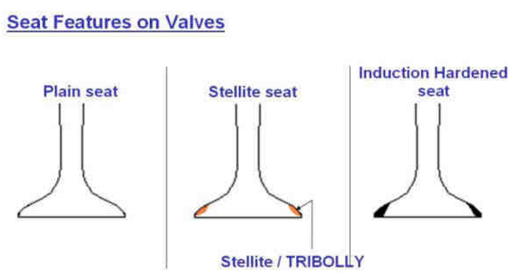

Fig.1.4: Seat Features On Valve

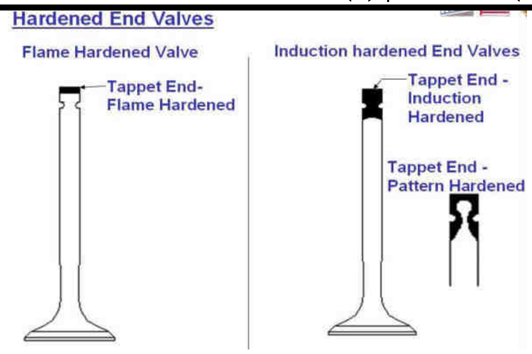

Fig.1.5: Hardened End Valves

1.5. Equipment :

- The electrical upsetter comprises of the main heating transformer, which is mounted within the machine frame and is air-cooled.
- The SCR control circuit permits control of heating power from 20% to 100% of rated capacity
- In Hasen claver upsetters current is controlled by tap change method.

1.6. Principle :

- The electrical upsetter supplies heat in the form of current from the top stationary anvil and pressure on the bottom movable anvil known as upset pressure.
- The principle involved here is decrease in length on one side of the cut bar bringing about increase in cross-sectional area at the other end of the bar, forming a bulb.
- This bulb is in hot condition and has to be moulded

2. Principle of Heat Treatment :

- Involves the transformation or decomposition of Austenite.
- Cooling rate plays an important role in transformation
- Slow cooling transforms to Pearlite
- Rapid cooling transforms to Martensite
- Heat Treatment is effective only with certain Alloys.

2.1. Stages in Heat Treatment :

- Heating
- Soaking
- Cooling

2.2. Types of Furnaces

- According to Working Environment
- According to type of Work.

2.3. According to working Environment

- Air circulating Furnace
- Protective atmosphere Furnace
- Special atmosphere Furnace

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2.4. According to Type of work:

2.4.1. Batch Furnace

A Batch of parts is charged for Heat Treatment, It is taken out after Heat Treatment, Then a second batch is charged.

2.4.2. Pit Furnace

The parts are kept in Vertical Position.Small parts can be loaded in a Bucket and Charged.

2.4.3. Box Furnace

It is used mainly for heat treatment of small parts.The parts are charged &unloaded manually from the Furnace

2.4.4. Continuous Furnace.

It is used in mass production. It reduces labour time in loading& unloading. Highly consistency. The work pieces are carried through the heating chamber on a conveyor chain made up of heat resistance alloy steel.

Hardening to develop high hardness to resist wear & cut metal.To improve Strength, Elasticity, Ductility & Toughness.

2.5. Tempering

Hardened Steel is Brittle, Hard, Highly Stressed .this is Unsuitable for most uses directly.

2.5.1. Properties of Tempered Steel :

- Hardness & Brittleness Reduced
- Tensile Strength &
- Yield Strength decreases
- Ductility & Toughness increases

Table 1 :Quenching Rate/Medium

Quenching medium	Rate of cooling	Structure	Hardness
Furnace	Very slow	Coarse pearlite	10-20
Air	Medium	Fine pearlite/ Sorbite	20-30
Oil	Fast	Very fine pearlite	30-45
Water	Very Fast	Martensitic	50-65

2.6. Factors Affecting Hardening

- Carbon Content
- Quenching rate
- Work size
- Alloying content.

2.6.1. Stress Relieving

Involves Heating to lower critical temperature Holding at this temperature for sufficient time. Uniform cooling In air. No Microstructure changes.Purpose to relieve internal or locked in stresses.

2.6.2. Annealing

Purpose of Annealing is to Relieve the internal Stresses, to increase the Machinability, to retain grain size.

2.6.3. Method of Annealing

Annealing is the process which involves, heating a work piece to a particular temperature maintaining it at that temperature for a particular time and then gradually cooling. Undesired stresses and structural hardness are removed in this way.

2.6.4. Normalizing Process

It is the process of heating the steel and cooling it an atmospheric air.

2.6.5. Normalizing - Purpose

Depending upon the carbon content normalizing process transforms the grain structure, which are too coarse, and results in a new and uniform fine grain structure.

2.6.6. Stabilizing - Purpose

To improve the corrosion and wear resistance of the work piece.

2.6.7. Stabilizing Process

It is the process of stress relieving for the components, which have undergone surface coating (Chromium Plating)

2.6.8. Solution Treatment & Ageing

Solution Treatment is a process of heating the austenite steel namely 21.4N; 21.12N; at a temperature of 1120°C and cooling it suddenly in water. Ageing is usually done after solution Treatment.

2.6.9. Solution Treatment & Ageing Purpose

To increase the Mechanical properties of the component. It is usually done to increase the Hardness of the component.

2.6.10. Solution Treatment & Ageing Method

It is usually done at a temperature of 700° to 800°C for a period of 5 hrs. to 2 hrs. min. It is usually done in air circulated tempering furnaces.

2.6.11. Shot Blasting - Purpose

Shot Blasting is an operation to remove scales on the Forgings/Heat Treatment.

2.6.12. Defect in Heat Treatment

- Low Hardness
- Soft spots
- Oxidation and Decarburisation
- Over heating and burning
- Formation of cracks
- Distortion and warping

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Low Hardness Due to lower hardness temperature ,Insufficient soaking time, Delayed quenching, Slower cooling rates, Higher Tempering temperature, Soft Spots due to,Improper heating ,Not uniform, Varying Hardness at different points, Presence of Foreign particles – avoid,Keeping larger components – avoid, Improper handling of components avoid, Spray quenching practice, Quench Cracks ,Due to the Stress produced during transformation of austenite to martensite ,It is a serious Phenomenon, Valve with Quench crack cannot be used

2.2.13. Straightening

Due to Forging and Heat Treatment valves are subjected to Heavy distortion and to remove this the Straightening is done. It is done using Stem and Angle Rollers.

2.6.13. Grinding :

Centerless grinding is a method of material removal through grinding, similar to centered grinding except for the absence of the spindle. It has high through-put, i.e. large number of parts can be manufactured in a short time.

The work-piece is set-up between the regulating wheel (or back up wheel) and the grinding wheel, and is supported by the work blade (or work rest). Both wheels are rotated in the same direction. The work rest is located between the wheels. The work is placed upon the work rest, and the latter, together with the regulating wheel is fed forward, forcing the works against the grinding wheel. The axial movement of the work past the grinding wheel is obtained by tilting the regulating wheel at a slight angle from horizontal. An angular adjustment of 0 to 8 or 10 degrees is provided in the machine for this purpose.

2.6.14. Turning :

Turning is the process whereby a lathe is used to produce "solids of revolution". It can be done manually, in a traditional form of lathe, which frequently requires continuous supervision by the operator, or by using a computer controlled and automated lathe which does not. This type of machine tool is referred to as having computer numerical control, better known as CNC. and is commonly used with many other types of machine tool besides the lathe.

When turning, a piece of material is rotated and a cutting tool is traversed along 2 axes of motion to produce precise diameters and depths. Turning can be either on the outside of the cylinder or on the inside to produce tubular components to various geometries.

Table 2 : Friction Welding Process Parameters

BAR DIA	UOM	BAR DIAMETER				TOLERANCE (+/-)
		6.50-8.40	8.40-9.80	9.80-12.00	12.00-14.00	
Soft force	tonnes	0.2	0.3	0.3	0.3	0.1
Friction force	tonnes	0.6	0.8	0.9	1.4	0.1
Upset force	tonnes	2.1	2.7	3	4.8	0.5
Soft force time	sec	0.5	0.5	1	1.5	0.5
Upset time	sec	0.5	0.5	0.5	1	0.1
Upset force delay	m.sec	100	100	100	100	NO
Set burn off	mm	4	4	4	4	0.3
Spindle speed	rpm	2000	1900	1900	1800	NO
Shrinkage low limit	mm	MINIMUM 6.5				
Shrinkage high limit	mm	AS PER PSC(O.L AT F.W)				
Clamp opening position	mm	DEPENDS UPON THE STEM LENGTH				

3. Problem Identification:

3. 1. Lead time & customer satisfaction point of view:

- On time delivery of Friction Welding Ground Bar from Subcontractor is critical for MDI valves dispatch (Daily despatch to M&M)
- It becomes vital to make improvements in the process flow so that on-time delivery to the customer can be ensured.

3.2. Environmental Management system point of view:

- Reduction of coolant mixed grinding muck is important in view of wastage reduction in bar grinding.

3.3. Problem Definition

Despatch of valves to the customer as per the scheduled plan by reducing the process time by eliminating some operations through process modification.

3.4. TARGET:

3.4.1. About the Process

1. The raw material bars are first friction welded.
2. Deburring is done for flash removal.
3. These bars are sent out for bar grinding operation.
4. After receiving grounded bars from the subcontractor they are upsetted,forged,straightened and given as input to rough centreless Grinding operation

3.4.2. Study Current Situation:

After the friction welding the bars are sent for bar grinding operation to the subcontractor.The lead time for for receiving the ground bars from the subcontractor is 2 days The Dispatch of valves to the customer as per schedule was getting delayed due to delay in supply of friction welded grounded bar by the Bar grinding subcontractor.

Fig.2 : Friction Welding Operation In "Pin To Pin" Process

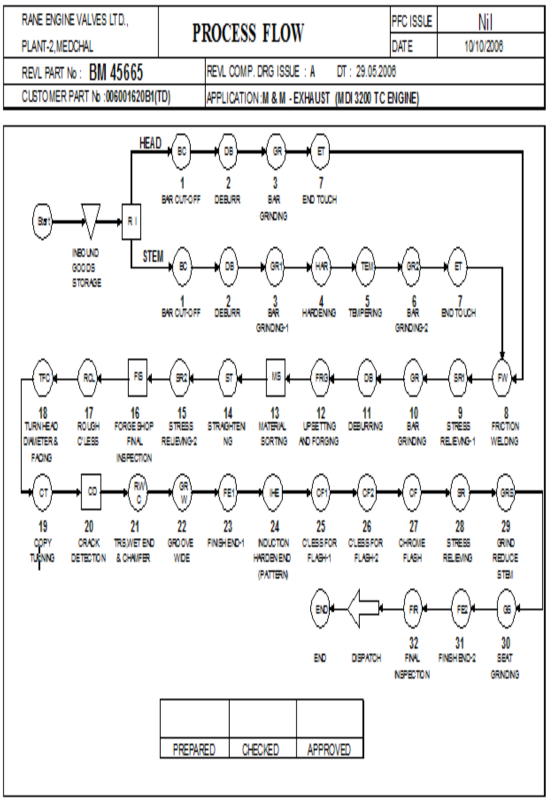

Fig.4 : Valve Process Flow with Pin to Pin Friction Welding

Table 3 : Friction Welding Process Parameters

BAR DIAMETER	UOM	6.50-8.40	8.40-9.80	9.80-12.00	12.00-14.00	TOLERANCE (+/-)
Soft force	tonnes	0.2	0.3	0.3	0.3	0.1
Friction force	tonnes	0.6	0.8	0.9	1.4	0.1
Upset force	tonnes	2.1	2.7	3	4.8	0.5
Soft force time	sec	0.5	0.5	1	1.5	0.5
Upset time	sec	0.5	0.5	0.5	1	0.1
Upset force delay	m.sec	100	100	100	100	NO
Set burn off	mm	4	4	4	4	0.3
Spindle speed	rpm	2000	1900	1900	1800	NO
Shrinkage low limit	mm	MINIMUM 6.5				
Shrinkage high limit	mm	AS PER PSC(O.L AT F.W)				
Clamp opening position	mm	DEPENDS UPON THE STEM LENGTH				

Remarks:

FRICTION FORCE = (CROSS-SECTIONAL AREA OF THE STEM x 12kg)/1000

UPSET FORCE = 3.4 x FRICTION FORCE

Table 4 : Product Parameters

PARAMETERS & CHARACTERISTICS	SPECIFICATION/TOLERANCE	VERIFICATION EQUIPMENT	SAMPLE SIZE & FREQ. OF INSP.
Bar length/ valve length(OL) after friction welding	Spec. as per route card with tolerance of ±0.50	Venier/ fixture-HS with dial gauge	1 per 100 Nos. FOA (5 Nos.)
Runout	0.4mm TIR Max.	Fixture-STR with	5 Nos. per 100 Nos.

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		0.01 dial gauge	5 Nos. at FOA
Tensile test	**For all parts** At weld joint : 92 Kgf/mm^2 Min **For Duetz parts** At weld joint : 92 Kgf/mm^2 Min On Head : 97 Kgf/mm^2 Min On Stem : 112 Kgf/mm^2 Min **For Cummins part No. 41435** At weld joint : 700 N/mm^2 Min	Universal Testing Machine (UTM)	1 No. at the time of setting 1 No. at the end of the batch **For Deutz** 1 No. at setting/shift beginning and thereafter 1 No. after lunch and 1 No. at shift end/bath completion 1 No. at the time of setting
Visual inspection	No flash allowed after de-flash	Visual	1No. at the time of setting or at the time of tip indexing/changing.

Tensile strength

Friction welding operation was carried with Head to pin and some checks were conducted to know the mechanical properties of the welded joint.

Tensile strength for different diameter bars after friction welding

(a) Bar diameter = 6.90 mm

Reqiired tensile strength = 89-134 kgf/mm^2

Sample.no	Tensile strength (kgf/mm2) (Pin to Pin)	Tensile strength (kgf/mm2) (Head to Pin)
1	110	115
2	107	110
3	111	114
4	114	113
5	112	105
6	105	109
7	108	111
8	109	114
9	113	113
10	108	107

TABLE 5 : Tensile strength for different diameterbars after friction welding

(b)

Bar diameter = 8.65mm

Reqiired tensile strengt = 91--113 kgf/mm^2

Table 6: Tensile strength for different diameterbars after friction welding

Sample.no	Tensile strength (kgf/mm2) (Pin to Pin)	Tensile strength (kgf/mm2) (Head to Pin)
1	110	104
2	107	102
3	111	108
4	114	108
5	112	109
6	105	106
7	108	110
8	109	111
9	113	112
10	108	114

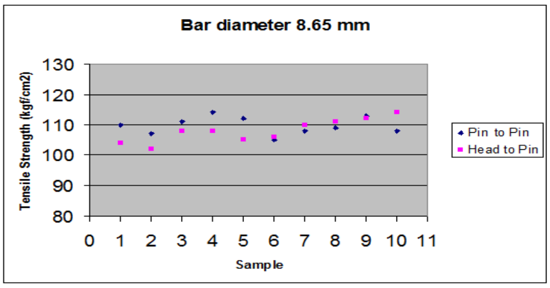

Fig.5 : Tensile Strength

(c)

Bar diameter = 9.10 mm

Reqiired tensile strength = 91-113 kgf/mm2

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Sampl e.no	Tensile strength (kgf/mm2) (Pin to Pin)	Tensile strength (kgf/mm2) (Head to Pin)
1	105	100
2	110	104
3	109	102
4	108	112
5	110	111
6	107	108
7	110	112
8	112	113
9	107	109
10	109	112

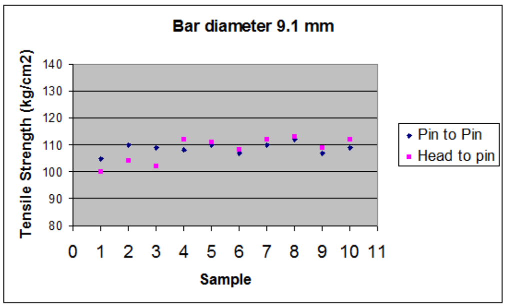

FIG 6 : Tensile strength

(d)

Bar diameter = 10.30 mm

Reqiired tensile strength = 91--111 kgf/mm2

Table 7: Tensile strength for different diameterbars after friction welding

Sampl e.no	Tensile strength (kgf/mm2) (Pin to Pin)	Tensile strength (kgf/mm2) (Head to Pin)
1	112	110
2	110	97
3	96	111
4	109	108
5	106	104
6	102	105
7	101	97
8	96	96
9	95	102
10	94	96

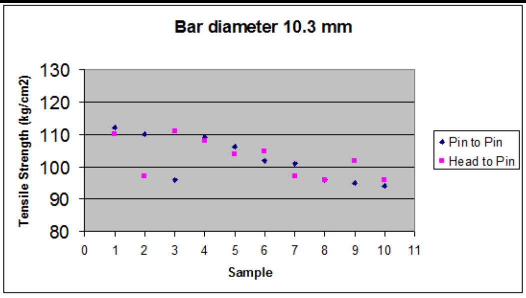

Fig.7:Tensile strength

From the above data it is clear that the tensile strength for different diameter bars are within the specified ran

Rough centreless operation

After friction welding the valve is deflashed for removing burr and flash at the welded joint.After heat treatment and straightening operations the material is kept for rough centreless operation.

Stem Runout

Stem Runout data after rough centreless operation

Maximum stem runout allowed = 10 Microns

Sample.no	Stem Runout (in Microns) (Pin to Pin)	Sample.no	Stem Runout (in Microns) (Headto Pin)
1	4	1	3
2	7	2	4
3	5	3	6
4	5	4	5
5	4	5	7
6	3	6	4
7	5	7	3
8	6	8	5
9	4	9	6
10	4	10	4
11	6	11	5
12	5	12	6
13	4	13	4
14	2	14	3
15	6	15	3
16	5	16	4
17	4	17	5
18	3	18	6
19	4	19	3
20	6	20	2

Fig.8 : Stem Runout

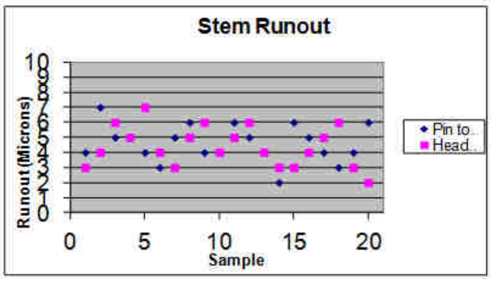

Fig.9 : Stem Runout

From the above data and the chart it is evident that the stem runout is within the specified range in"Head to Pin" process.

II. Conclusion

The Lead time in producing the valve is reduced by 2 days by eliminating Bargrinding,Deburring,Sorting and Stress relieving operations.The elimination of these operations resulted in the reduction of cost of manufacturing the valve.Total cost saving includes operation cost and the raw materail cost.

To achieve and sustain the above benefits,the new process is standardized as follows:

- The new process flow chart is standardized
- The SOP'S are amended as per the new process flow.
- The raw material bars are procured as per the requirement of modified process.

III. FUTURE SCOPE OF PAPER

- This Head-Pin friction welding process can be straight away applied to the TML and FML bi-metal valves, those are having head length of above 50mm stem diameter above 7mm valves.
- There is a scope for implementation of head forging concept for the valves below 50mm head length and below 7mm stem diameter by developing new fixtures in forging as well as friction welding operations.
- There is a scope for low cost automation for loading the head and stems in friction welding machine to introduce multi manning or to increase the output of the process.

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