Retrofitting of Machine by Design and Implementation of Self Locking of Worm Gear for Vertical Axis

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Abstract— Replacement of the high value machine tool or special purpose machine tool is not financially feasible and the machine has a large work envelope with high quality and substantial machine components. Slide way grinding machine manufactured by Waldrich Coburg Company in 1994, is a very expensive machine with high precision of work. It's having a problem of vertical axis falling down by 10-15 mm due to gravitational force at the time of working. The problem is resolved by retrofitting of the worm gear pair by applying theory of self-locking; which is dependent on lead angle of worm gear and coefficient of friction between material of worm shaft and gear. After retrofitting, it's working very precisely and results obtained are tremendously good. Now vertical axis is working with a very high reliability & accuracy and it doesn't fall down in any condition.

Key words: Machine Tool, Retrofitting, Vertical Axis, Worm Gear Pair

I. INTRODUCTION

Since all customers today have access to over world market due to globalization, liberalization etc. they have option open to change more frequently their choice as per requirements. As they have more variety of products with improved quality, reliability at lower price. Hence market life of product reduces such demands cannot be met by conventional ageing manufacturing machine tools because they limited capability, flexibility, precision and become obsolete with time. In countries with developing economics like India since capital constraints always prevail, up gradation of exiting machine tools through retrofitting and reconditioning is best possible answer to them. Retrofitting is lead to cost effective modernization of existing machine tools [1].

Retrofitting is the process of replacing the machine components or obsolete operating systems of machine tool to extend its useful life. Rebuilding and remanufacturing typically include a wear and tear parts and absolute system retrofit. The anticipated benefits include a lower cost investment for retrofitting than purchasing a new machine tool and an improvement in uptime, precision i.e. quality and availability. But there are often other unanticipated benefits to retrofitting including lower energy costs, higher performance and a new level of manufacturing data accessibility of machine [5].

Machines maintained at an optimum quality, also need to be retrofitted after years of productive operation in order to increase their economic efficiency. If we look at the continuously increasing demands on quality and the rationalization involved, it is not enough to re-condition the existing machine tool as good as new. Changing given parameters or add new components and sub-assemblies require constructive assessment and design. In a lot of cases these measures lead to higher efficiency then it would be achieved with a new standard machine. Therefore a retrofit is an economical alternative to buying a brand new machine [4].

Retrofitting of senescent machine tools has a significant role to play in developing economics like India due to following reasons [1], [4]:

- Restored or often increased productivity
- Increase of machine performance
- Use of state of the art technology and components
- Wider machining range
- Availability of control components and spare parts is guaranteed again
- Prohibited cost of new machine
- Lack of adequate foreign exchange resources for machinery import.

Generally machines have counter weight to carry spindle load i.e. equivalent counterbalancing weight that balances a load. It opposes to fall down of spindle by gravitational force. But Slide way grinding machine don't have counter weight to balance load of vertical axis. It's totally depending on mechanical or servo brake to balance the load of vertical axis. When mechanical brake is working it doesn't fall down but at the time of servo, mechanical brake released and servo brake get switch on. At the time of mechanical brake release worm pair moves in reverse direction and vertical axis fallen down by 10-15 mm and caused accident number of times.

After studied this problem, we observed that vertical axis worm mechanism rotate without driver rotation by gravitational force and vertical axis falls down. To resolve this problem we have first priority to apply theory of self-locking to eliminate this problem and reduce reversibility of worm gear pair.

II. METHODOLOGY

A. Concept of Self Locking

Self-locking is a unique characteristic of worm gear that can be put to advantage. It is the feature that a worm cannot be driven by the worm gear. It is very useful in the design of some equipment, such as lifting, in that the drive can stop at any position without concern that it can slip in reverse. However, in some situations it can be detrimental if the system requires reverse sensitivity, such as a servomechanism. Self-locking does not occur in all worm meshes, since it requires special conditions as outlined here. In this analysis, only the driving force acting upon the tooth surfaces is considered without any regard to losses due to bearing friction, lubricant agitation, etc. The governing conditions are as follows [2]:

Let F_{u1} = tangential driving force of worm,

Then, $F_{u1} = F_n (\cos\alpha_n \sin\gamma - \mu \cos\gamma)$ …….. (1)

Where:

α_n = normal pressure angle,

γ = lead angle of worm,
μ = coefficient of friction,
F_n = normal driving force of worm.

If $F_{u1} > 0$, then no self-locking effect in worm. Therefore, $F_{u1} \leq 0$ is the critical limit of self-locking.

Let α_n in (1) be 20°, then the condition $F_{u1} \leq 0$ will become,

$(\cos 20° \sin\gamma - \mu \cos\gamma) \leq 0$ …….. (2)

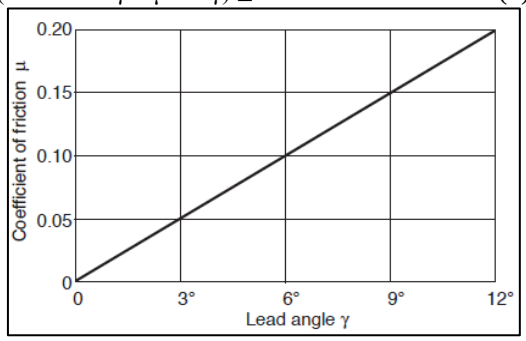

Fig. 1: Critical Limit of Self-locking of Lead Angle γ and Coefficient of Friction μ

B. Design Calculations

By requirement:
$\alpha_n = 20^o$
$\gamma = 3.72^o$
$\mu = 0.056$
Therefore,
$F_{u1} \leq 0$ will become (2)
$(\cos 20° \sin 3.72° - 0.056 \cos 3.72°) \leq 0$
$-0.504 \leq 0$
By (2) it becomes successful self locking worm pair.

To make self locking pair of worm gear, we required to reduce lead angle and increase coefficient of friction between both materials. For self locking pair of worm required lead angle is less than 6 degree and coefficient of friction is greater than 0.045. So we reduce lead angle of gear from 17.78 degree to 3.72 degree and increased coefficient of friction from 0.03 to 0.567 by replacing worm wheel material. As per design standard backlash for this gear pair is allowed up to 0.3 mm, it is maintained at time of manufacturing [3]. All design data of existing and new gear pair as below:

C. Design Data of Worm Gear Pair:

1) Worm Shaft:

Sr. no.	Parameter	Unit	Existing	New
1	Outer diameter	Mm	70	70
2	Pitch centre diameter	Mm	58	62
3	Module	mm	6	4
4	Helix direction	degree	Right hand	Right hand
5	Pressure angle	degree	20	20
6	No. of starts	digit	3	1
7	Centre distance	mm	125	125
8	Lead angle	degree	17.78	3.72
9	Material		20 Mn Cr 5	20 Mn Cr 5
10	Heat treatment		Case carburize harden	Case carburize harden
11	Worm thread finish		N6	N6

Table 1: Worm Shaft

2) Worm Gear:

Sr. no.	Parameter	Unit	Existing	New
1	Throat diameter	mm	204	196
2	Pitch centre diameter	mm	192	188
3	Module	mm	6	4
4	Helix direction	degree	Right hand	Right hand
5	Pressure angle	degree	20	20
6	No. of starts	digit	3	1
7	No. of teeth	mm	30	46
8	Material		Phosphor bronze	Cast iron CG25 Centrifugally cast with no blow holes and porosity
9	Teeth cutting		Finish hob	Finish hob
10	Worm thread finish		N6	N6

Table 2: Worm Gear

3) General Specifications:

Sr. No.	Parameter	Unit	Existing	New
1	Center distance machine with worm	Mm	125	125 +0.0/-0.2
2	Coefficient of friction between pair		0.03	0.05 to 0.06
3	Gear ratio motor to worm gear		10 to 1	46 to 1
4	z- axis slide rapid speed	mm/ min	2000	425

Table 3: General Specifications

D. Drawings of Gear:

1) Worm Shaft:

Fig. 2 shows auto cad drawing of worm shaft with all dimensions in mm.

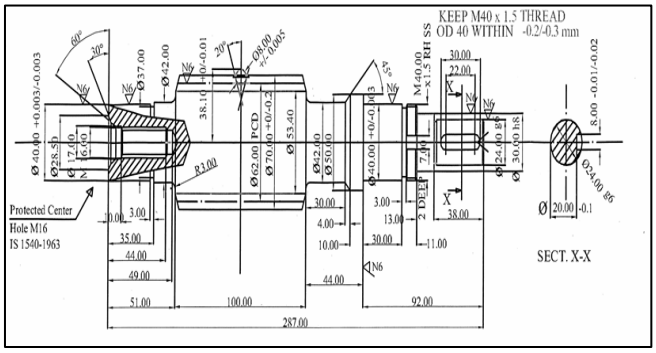

Fig. 2: Drawing of Worm Shaft

2) Worm Wheel:

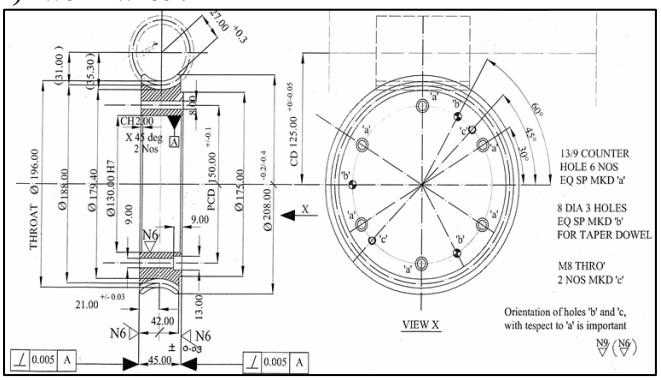

Fig. 3: Drawing of worm wheel

III. Result and Discussion

After retrofitting worm gear pair, testing of machine is taken. It gives tremendously good results as per requirement and it doesn't falls down in any condition. Now machine gives good results with 1 micron accuracy. Overdrive distance of vertical axis is given in observation table as below:

Sr. No.	DISTANCE (MM)	Fall Down Observations (MM)	
		Existing	New
1	0-100	4.045	0.000
2	100-200	2.360	0.000
3	200-300	10.863	0.000
4	300-400	4.608	0.000
5	400-500	12.670	0.000
6	500-600	9.899	0.001
7	600-700	10.040	0.000
8	700-800	6.462	0.000
9	800-900	13.835	0.001
10	900-1000	14.536	0.000

Table 4: Result

IV. Conclusion

By developing worm gear pair of grinding machine by retrofitting it, machine works very accurately and repetitively, it gives tremendous good result than existing. It saves lot of money of company and also increased production.

As new developed retrofitted grinding machine is done by replacing worm gear pair, set up cost is so much less than new one and production rate is very high. So it is useful for mass production.

Accuracy of a job manufactured on retrofitted grinding machine is also high. So repeatability and dimensional stability of manufactured part is achieved.

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