Rejuvenating machine tools

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Conventional machines become phenomenally productive and flexible by retrofitting them with CNC controllers. Refurbishing and upgradation of old CNC machines restore them close to their original performance levels. Today, the concept of remanufacturing machine tools is emerging. Additionally, these cost-effective solutions of automation are equally beneficial to small, medium and large industries. Read on for more …

The first NC machine developed at MIT in 1959 was a giant leap in machine tool control, which introduced flexible automation. Today, a wide variety of CNC machines are used for metal cutting, sheet metal working, non-traditional machining, inspection, etc. Along with the developments in drives, sensors and controls of CNC machines, there have been tremendous growth in associated areas such as cutting tools and CNC programming software. Aerospace, automotive and other engineering industries and tool rooms have been benefiting from the flexibility, accuracy and speed of CNC machines. Inspite of these benefits, many industries are reluctant to make huge investments in new CNC machines. This is due to the fact that different levels of automation through rejuvenation of old machines are available to them with different cost implications and commensurate benefits.

Metal working mostly involves cutting and forming using both conventional as well as CNC machines. Table 1 shows indigenous production of metal working machines for a period of three years. Annually, Indian industries buy approximately 4,000 machines worth Rs 600 crore, locally. Out of these, about 2,000 are CNC machines worth Rs 400 crore. In addition, the country also imports CNC machines of almost the same quantum. Therefore, the annual machine tool consumption in India is about Rs 1,200 crore (8,000 machines) of which Rs 800 crore (4,000 machines) is for CNC machines.

All CNC machines require some kind of rejuvenation after about 10 years of their life. If one assumes that at least 50% of these are taken up at about 30% of the purchase price, then this is worth Rs 120 crore (2,000 machines). Assuming that about 5% of the conventional machines come for some kind of rejuvenation at a cost of twice their purchase price, this market is worth Rs 40 crore. Therefore, the turnover of Indian machine tool rejuvenation industry can be estimated at Rs 160 crore. This figure will go up further since a fraction of hundreds of machines accumulated over the last 50 years will also come for rejuvenation. Furthermore, hundreds of used/scrapped machines are brought into the country every year. In addition, India's potential to emerge as the hub of global machine tool rejuvenation, can increase the turnover to Rs 2,000 crore. Given this market size, the desire of machine tool users to enhance the machine's life & capabilities, and the machine building skills available within the country, the machine tool rejuvenation industry is poised to grow in a big way. This industry dovetails very well with used machinery trading which is booming, thanks to the relaxation of government regulations on used machinery import. In fact several OEMs have already started buying back their old machines, rejuvenating and selling them. In addition, quite a few third parties are pitching in.

Table 1: Production of metal working machines in India (Courtesy: IMTMA)

		Year 2000-2001		Year 2001-2002		Year 2002-2003	
		Qty	Value (Rs crore)	Qty	Value (Rs crore)	Qty	Value
Metal forming machines	Conv.	331	95.5800	255	83.5890	422	50.8000
	CNC	101	14.7485	105	15.6559	166	24.6000
	Total	432	110.3285	360	99.2449	588	75.4000
Metal cutting machines	Conv.	2645	194.8609	1646	142.3357	1570	112.5000
	CNC	1185	279.4744	1204	269.8470	1756	360.8000
	Total	3830	474.3353	2850	412.1827	3326	473.3000
Metal working machines	Conv.	2976	290.4409	1901	225.9247	1992	163.3000
	CNC	1286	294.2229	1309	285.5029	1922	385.4000
	Total	4262	584.6638	3210	511.4276	3914	548.7000

Import almost equals local production

Machine tool rejuvenation

Mechanical hardware of CNC machines has an uninterrupted life of about 10 years. It can comfortably work for the next 10 to 20 years if some minor repairs such as change of liners, backlash correction, alignment and pitch error calibration are done. It is not sensible to scrap the machine even at the end of this period since the castings would have released all stresses and become structurally more stable. In fact, castings are like wine - old is better than new. Therefore, they should be remanufactured to have another 20 years of useful life.

Rapid developments in electronics lead to faster obsolescence of CNC controllers. Therefore, the life of the controller is much shorter than the mechanical hardware. The original controller becomes pathetically inferior to the latest ones within two years. Some of the controllers come out with different hidden versions. Therefore, spares for even the same model are not available or too expensive.

When the CNC machines complete their useful life or fail to meet the Cp and Cpk requirements, these can be given a fresh lease of life through certain activities. These are referred to as machine tool rejuvenation and can fall into three broad categories:

- Retrofitting
- CNC controller upgradation
- Remanufacturing

Retrofitting

Retrofitting converts the conventional machine into a CNC machine by replacing its old gear boxes and lead screws with ball screws and servomotors. During 1983-98, commonly retrofitted machines were only small lathes and knee type milling machines. Occasionally HMT AZ11 type of boring machines were also retrofitted. These retrofits never worked as full-fledged CNC machines. Compromises in accuracy and performance in these low cost retrofits were accepted in those days. Customers never took the risk of retrofitting beyond this level. During this period, the retrofitting market was dominated by companies like Electronica, KEC and Technofour.

The present scenario in retrofitting is substantially different, thanks to improved skill levels and customer awareness. Customers are now ready to retrofit more complicated machines like cylindrical grinders, borers, crankshaft milling and grinding machines, camshaft grinders, vertical turret lathes, huge roll turning lathes, roll grinders, tool and cutter grinders, gear cutting and grinding machines, etc. Not only has the confidence of the customers increased in retrofitting; they have also started demanding productivity and accuracy from the retrofitted machines as good as the new machines. The approximate cost of retrofitting various machines is given in Table 2.

CNC controller upgradation

Upgradation of CNC controller involves replacement of the entire electrical and electronics of an existing NC/CNC machine. This is the most economical solution among the three types of rejuvenation since the mechanical hardware is not attended. The influx of used machines into the country increased from 1995. In more than 90% of these cases, the controllers need to be replaced. Furthermore, technological obsolescence coupled with lack of spares/ support necessitates replacement of the controllers with the latest ones of the same make or a different one; this may be required at least every 8 to 10 years to exploit the full benefits of the entire CNC system. There are a number of players in the market to carry out this upgradation. They are mostly

Table 2: Cost of retrofitting conventional machine into a CNC machine

Type of machine	Cost of retrofitting in percentage of new machine
Lathe: up to 8" chuck diameter	120 - 130%
Lathe: 12" to 24" chuck diameter	80 - 100%
Lathe: >20" chuck diameter and >3,000 mm between centres	40 - 60%
Knee type milling machine	120 - 130%
VTL: up to 1,600 mm chuck diameter	40 - 60%
VTL: 4,000-6,300 mm chuck diameter	30 - 40%
Crankshaft/ Camshaft grinders	30 - 40%

Note for Tables 2 and 3:

- Cost of used machine is not considered in the percentage calculations. To get the correct comparison with new machine, add the cost of used machine
- For comparison, government taxes and levies are not considered
- The above percentages show the conversion cost when compared to the new machine cost

Table 3: Cost of CNC controller upgradation and remanufacturing

Type of machines	Cost in percentage of new machines	
	CNC Controller upgradation	CNC remanufactu-ring
CNC lathe: up to 8" chuck diameter	50%	90 - 110%
CNC lathe: 12" to 24" chuck diameter	30 - 40%	50 - 60%
CNC lathe: >20" chuck diameter and >3,000 mm between centres	15 - 20% 1	25 - 30%
Small VMC: up to 400 mm x 630 mm table	60 - 70%	90 - 110%
Larger VMC: above 400 mm x 630 mm table	30 - 40%	50 - 60%
Small HMC: up to 500 mm x 500 mm table	60 - 70%	90 - 110%
Large HMC: above 500 mm x 500 mm table	20 - 30%	30 - 40%
Floor borer	15 - 20%	20 - 30%
Crankshaft/ Camshaft grinders	10 - 20%	20 - 30%

ex-employees of machine tool manufacturing companies or the people with maintenance background from big manufacturing companies. The approximate cost of controller upgradation is given in Table 3.

Remanufacturing

Remanufacturing old machines involve complete replacement of all mechanical, electrical and electronic parts except the basic castings. After remanufacturing, the machine is expected to work like a new CNC machine without any compromises. This trend for remanufacturing started in 2001. The norms for Cp and Cpk, especially in the automotive sector, had become very stringent by then which demanded higher productivity and rejection-free output from CNC machines. Gone are the days when the machines were kept in running conditions by some means or the other, and customers looked upon remanufacturing as a means to achieve these goals. The approximate cost of remanufacturing for various machines is given in Table 3. The demand for remanufacturing is very high but there are very few players. Many OEMs take up remanufacturing of their own machines. At present, HMT and Sharpline are the active players in India.

It may be noted from Table 2 and 3 that rejuvenation of small machines by third parties is not economical. This is because small machines are sold in large numbers and hence the OEMs put in great efforts in optimising their design for performance and cost. Therefore, when small machines are required, it is advisable to buy them new rather than rejuvenating old machines by third parties. The price of the new machine increases exponentially with its size due to less numbers sold. However, the increase in the cost of rejuvenation with its size is not so steep. Therefore, when medium to large CNC machines are required, rejuvenation is preferable to new purchase; the same is true for specialised machines such as huge lathes, large VMCs and HMCs, crankshaft and camshaft grinders, tool and cutter grinders, etc due to their low volume of sale. A typical machine tool rejuvenation factory is shown in Figure 1.

Features of machine tool rejuvenation industry

By and large, machines of several makes and processes are brought in for rejuvenation. Therefore, this industry requires people with versatile machine building skills. They should have adequate knowledge in kinematics, metrology, vibrations, CNC controllers, machining, CNC programming and software development. Only a few in the company will have these versatile skills gained through years of experience in machine building or maintenance. These experts do conceptual and configurational design including the selection of the controller and cost estimates. Implementation of individual subsystems is carried out under their supervision by other employees each specialising in different fields. The employees fall into three broad categories:

- Machine builders
- Control experts
- Application specialists

More often than not, a considerable portion of rejuvenation takes place at the customer's site. Therefore, employees have to go on long tours frequently. Stringent legal formalities imposed by the factory act have to be followed when employees are deputed to work at a customer's site. These travels and regulations make the job unattractive.

The condition of the used/scrapped machine supplied for rejuvenation influences the quantum of work and hence the cost and time. User's perception of the condition based on external inspection may not reflect its actual status accurately. All the documents received along with the new machine may not be available now and many elements such as covers, rotary table,

Figure 1: A typical machine tool rejuvenation factory

Figure 2: Nexus Union conventional crankshaft grinder after retrofitting into a CNC crankshaft grinder

etc may be missing. Therefore, cost and time estimates for rejuvenation should include adequate buffers to account for these uncertainties.

The scope for rejuvenation is not decided in one go; cost, taxation and knowledge of alternatives influence it.

Every machine that undergoes rejuvenation is a unique project requiring new engineering every time. The decisions are based on experience and gut feelings rather than rigorous design analysis. This is not the case when an OEM does rejuvenation since they have access to the original design documents.

Rejuvenation of small machines by third parties is not economical as discussed earlier; these should be left to the OEMs or their agents. Sometimes customers' expectations are too high. For instance, they may want to retrofit an ordinary grinding machine to use CBN wheel for faster production. Such demands require case by case study as this may be uneconomical for the existing structure.

Case studies

Rejuvenation of lathes and machining centres are well-established routine activities today. The following three case studies focus on different types of machines. These were hitherto carried out abroad due to the sheer size and/ or the stringent accuracy requirements. The first two belong to retrofitting and the last was the case of remanufacturing. Any rejuvenation ends with calibration using laser interferometer.

Case study 1: Retrofitting of Nexos Union conventional crankshaft pin grinder into a CNC crankshaft pin grinder

A Nexos Union conventional crankshaft pin grinder was supplied for retrofitting by Tata Motors, Pune. Its slides were hydraulically operated. It had been used for over 40 years and was received in dilapidated condition. The following were done during retrofitting:

- The guide ways were ground to remove the excessive wear and to get the required accuracy
- Turcite sheet was pasted on each female guide way and scrapped to the desired accuracy
- The hydraulic systems of the longitudinal and transverse slides were replaced by AC servomotors and ball screw assemblies. These became Z and X axes
- Marposs gauging, flagging and wheel balancing systems were incorporated to achieve the desired component accuracy
- The spindle of the work head also was provided an AC servomotor, which became C axis
- A newly built dressing unit comprising of U and V axes driven by AC servomotors and ball screws was incorporated to get different profiles on the wheel
- The grinding wheel spindle and bearings were refurbished to get a maximum surface speed of 45 m/s
- Sinumerik 840D CNC controller was integrated with the machine with complete wiring

The machine after retrofitting is shown in Figure 2. It is now a full-fledged 5-axes CNC crankshaft pin grinder. It is as good as the new machine at just about 30% of its price. Similar work has been executed for both pin and journal grinding on other makes of machines such as Landis, Norton and Newall, as well as on Toyoda multi-wheel journal grinder.

Case study 2: Retrofitting of Fortuna angular wheel head grinder into a CNC camshaft grinder

A very old Fortuna angular wheel head grinder was supplied by Tata Motors, Pune (Figure 3a). They wanted to convert this conventional grinder into a CNC camshaft grinder. The following were done during retrofitting:

- The guide ways were ground to remove the excessive wear and to get the required accuracy
- Turcite sheet was pasted on each female guide way and scrapped to the desired accuracy
- Grinding wheel infeed and longitudinal motions became X and

Figure3a: Machine received for retrofitting

Figure3b: Machine after retrofitting

Figure 3 Retrofitting of Fortuna angular wheel head grinder into a CNC camshaft grinder

Figure 4a: Machine received for remanufacturing

Figure 4b: Machine after remanufacturing

Figure 4: Remanufacturing of a floor borer

Z axes. The work head rotation became C axis. The fourth was W axis meant for dressing tool. All axes were driven by AC servomotors through ball screws of appropriate sizes

- Marposs wheel balancing system was incorporated to achieve better stability
- The grinding wheel spindle and bearings were refurbished to get a maximum surface speed of 45 m/s
- Siemens 840D CNC controller was integrated with the machine with complete wiring of the machine
- A CAM grinding software developed especially for this machine automatically creates the NC programme from the geometry of the cam profiles and the in-situ measurements. Thus the NC programme generated after each measurement accounts for wheel wear and other process variations resulting in excellent profile accuracy. This is one of the most complicated software developed indigenously. Such machines were sent abroad for retrofitting till date for want of this expertise

The machine after retrofitting is shown in Figure 3b. The Cp and Cpk values of the machine were achieved as per the requirements on different camshafts. Retrofitting of such machines today is becoming popular because of the cost effectiveness. Similar work has been executed on Schaudt camshaft grinders for Tata Motors, Jamshedpur and Ashok Leyland, Chennai and on Landis camshaft grinder for M&M, Igatpuri.

Case study 3: Remanufacturing of a Froriep floor borer

Saini Engineering, Mumbai bought a conventional floor borer of Froriep make in dilapidated at scrap value (Figure 4a). Only the castings of the bed, trolley and column were usable. They wanted this machine to be remanufactured into a three-axis CNC floor borer with traverses of 6,500mm x 3,000mm x 1,000mm. The required traverses along X and Y axes were slightly more than those of the original machine. The following were done during remanufacturing:

- Additional extensions of castings were fitted to the bed and the column to increase the strokes of X and Y axes by about 1,000 mm
- The guide ways were then scrapped to the desired accuracy
- Turcite sheet was pasted on each female guide way and scrapped to the desired accuracy
- New ball screws of adequate capacity were fitted for all the axes.
- A new ram slide assembly with built-in spindle was fabricated and fitted. The maximum spindle speed of 3,000 rpm was provided. Spindle was powered by an 18/22 kW AC motor
- Fanuc 0-iMB CNC controller was integrated with the machine with complete wiring

The machine after retrofitting is shown in Figure 4b. It is now a full-fledged three-axes CNC floor borer; it is as good as the new machine at just about 30% of its price. The machine was proved as per IMTMA test chart standards. On some of these machines, new hydrostatic arrangements have been provided for X axis.

Conclusions

The life of a CNC machine is limited by wear and tear of its mechanical elements and technological obsolescence of its controller. The old CNC machines can be rejuvenated through retrofitting, controller upgradation or remanufacturing.

Our well-established and mature CNC user base, accumulation of thousands of machines over the last five decades and influx of used/scrapped machines complemented by the availability of high skill at low cost point towards rapid growth of our machine tool rejuvenation industry along with the used machinery trading. If our OEMs and third party experts in machine tool industry take advantage of this opportunity professionally, India can become the hub of global machine tool rejuvenation. ✦

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