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Design and development of collet chuck

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Abstract - *The work piece materials from initial stage to finished products that is effectively used in engineering applications successfully needs to be held firmly in machines for machining process. One such application is the lathe where workpiece is held in chucks. Now days in CNC machines the automated chucks are used to hold the workpiece to successfully be machined, if in case this holding device malfunctions or there is a loss in gripping force which may lead to the insufficient machining.*

The spindle rotational speed of machine tools has become steadily higher due to the application of high speed cutting (HSC) technology. Higher spindle speed leads to greater demands on clamping systems. A basic problem with the application of jaw-chucks for clamping workpieces during high-speed turning is the huge centrifugal force that acts on chuck-jaws. This centrifugal force reduces effectiveness of the dynamic clamping force, making the HSC process dangerous. The three-jaw powered chuck is the standard work holding device for most CNC lathe users. This type of chuck is versatile enough to be used in a wide range of turning applications. However, it's not the best chuck for all jobs. The collet chuck is an alternate work holding device that, like the jaw chuck, also uses mechanical force to hold the part being turned. While a collet chuck lacks the capacity for the same wide range of workpiece sizes that a jaw chuck can accommodate, offers advantages related to speed, accuracy and productivity that may be crucial for certain jobs.

***Key Words*: chuck main body, mandrill, dober, chuck clamp, error of roundness.**

1. INTRODUCTION

When machining in lathe, the workpiece whose internal diameter to hold in chuck is slightly difficult. Sometimes internal diameter is very small as compared to chuck jaw, jaw size is greater than internal diameter. Then during such workpiece machining we have to use another work holding devices so that machining should be easy and economically. When machining this part currently we used three jaw chucks to firm. Internal surface are machined by boring operation and ready to further operation. Turning and facing operation has to be carried out on workpiece. If we see that there is lug provided on the one side of the workpiece to machine that side we have to either hold workpiece with internal diameter or hold the outer diameter of the workpiece. As a part is made up of aluminium alloy with pressure die cast so already parts are soft compare to the chuck body. Stiffness of workpiece and chuck are different so some time chatter mark may impinged on the workpiece. If we hold the workpiece in internal diameter side and rotate with high speed, due to improper clamping loss of gripping force of the chuck jaws has happened. Loosening of part may leads to the damage of lug, which cause rejection of that workpiece. Also loosening of parts may cause injuries to the worker which operates the machine. While holding worker should always check the proper clamping of workpiece by rotating parts with hand. This may lead either some injuries or pain in hand to worker.

1.1 Solution to solve the problem

Workholding includes any device used to present and hold a workpiece to a cutting tool. These devices include clamps, vises, chucks, fixtures and more. The decision about how to hold a part influences:

- Which surfaces or holes can be designated as references surfaces
- which surfaces can be machined in a single setup
- the overall accuracy of the machining process
- allowable cutting forces, which may include speeds and feeds
- the tool path
- possibly the tool size and shape

The work holding devices are used to hold and rotate the workpieces along with the spindle. Different work holding devices are used according to the shape, length, diameter and weight of the workpiece and the location of turning on the work. The three-jaw powered chuck is the standard work holding device for most CNC lathe users. This type of chuck is versatile enough to be used in a wide range of turning applications. However, it's not the best chuck for all jobs. The collet chuck is an alternate work holding device that, like the jaw chuck, also uses mechanical force to hold the part being turned. While a collet chuck lacks the capacity for the same wide range of workpiece sizes that a jaw chuck can accommodate, it offers advantages related to speed, accuracy and productivity that may be crucial for certain jobs. Several factors taken into the determination of which type of chuck would work better. When evaluating a collet chuck versus a jaw chuck for a given lathe application, take all of the following factors into account.

- **Spindle Speed -** A collet chuck tends to be the better choice for turning at particularly high levels of spindle rpm. One reason relates to the mass of the chuck. Given the same spindle horsepower driving a jaw chuck and a collet chuck, the more massive jaw chuck would take longer to accelerate up to speed. The acceleration time would extend cycle time and reduce productivity. Another reason relates to centrifugal force, which becomes a significant concern at high speeds because it increases as the square of rpm.

- **Operation to Be Performed -** A collet chuck applies clamping force all around the circumference of the part instead of just at select contact areas. The result is tight concentricity. This can be particularly significant for second-operation work where accuracy relative to the first operation is a concern. Even when a jaw chuck is used for the first operation, a collet chuck may be used for the second operation because of its precision clamping. A jaw chuck with bored soft jaws repeats within 0.0006 to 0.0012 inch TIR. A collet chuck typically provides repeatability of 0.0005 inch TIR or better. The collet chuck can also be adjusted for concentricity during installation to further improve secondary operation accuracy.

- **Workpiece Dimensions -** Collet chucks are best suited to workpieces smaller than 3 inches in diameter. A collet chuck may also impose a limitation on the workpiece length. Specifically, a collet chuck limits the machine's range of axial (Z-axis) travel, because its length is longer than that of a jaw chuck. When the machining length of a workpiece is so long that just about all of the available travel of the machine is needed to cut it, then this requirement will probably dictate the use of a jaw chuck.

- **Lot Size -** Very large and very small lot sizes both help make the case for a collet chuck. Where there are small lot sizes and lots of them, the collet chuck's advantage relates to change over time. Swapping jaws takes around 15 to 20 minutes for a standard jaw chuck or 1 minute on a jaw chuck specially designed for quick change, but the collet in a quick- change collet chuck can be changed in 15 to 20 seconds. The time savings add up where changeovers are frequent. Similar time savings related to clamping add up where lot sizes are large. A collet chuck takes less time to open and close than a jaw chuck, shaving cycle time by reducing the non-cutting time from one piece to the next.

2. DESIGN AND MANUFACTURING OF COLLET CHUCK

While designing collect chuck first we have to consider some parameter related to machine and also workpiece for which chuck is design.

- Chuck size should be greater than the workpiece size so that it firmly hold on to the chuck.
- Gripping force should be such that it holds tightly without bending the workpiece at high speed.
- Workpiece should not loosen in between machining operation so that any injuries to worker and damaged to machine not happen.
- Gripping force will be easily produced by machine and not exceed to damaged the parts.
- Chucks parts will be easily available or manufactured so that it become economical.
- Chuck parts size should be such that it easily connected to machine motion actuation system.

Before any design firstly we have to check

- Available machine centre
- Machine chuck spindle system
- Machine actuator to rotate spindle
- Available gripping force to clamp the workpiece
- Actuator for linear movement
- Available space for tool movement

2.1 Chuck main body

While designing the main body important thing is size of body. Chuck size would be greater than the job size so that job firmly fitted to the workpiece and while rotating with spindle it will rotate as solid body. We take the outer diameter of chuck body 170 mm so that job having outer diameter 146.5 mm is firmly fitted .while selecting width of body is dependent on the parts which are fitted in it. In chuck body we provide different bore diameter such as 65 mm, 80mm, 40mm at different length. Material for the chuck main body selected is EN 8. Different operation such as turning, boring, drilling is performed on the cylindrical block having dimension 172*82 mm. after operation we performed case hardening heat treatment process on chuck body so that surface become hard. Case depth surface heat treatment is produced on it so surface hardness increases up to 40-42 HRC.

2.2 Mandrill

As mandrill is inserted in the chuck main body, 40-0.01 mm as outer diameter and length 18 mm is provided so that this part is inserted in the chuck body portion whose internal diameter is 40 +0.02 mm. next to this portion increase in step of diameter 65 mm is provided so that this portion is fitted in the space in chuck body where internal diameter is 65mm. length of this portion is 10.50mm. Next to this for 1.50 mm length outer diameter is reduced to 50 mm so that the portion of workpiece which comes forward is easily rest on the chuck without any damaging to the workpiece. Next to these for 3mm length again outer diameter is reduced to 40.2mm and again reason for this is same as earlier to firm the workpiece strongly. Material for mandrill is EN 31. Operation performed on the parts is turning, drilling to make part of actual dimension. Grinding is performed at the end for finish surface of mandrill. After all machining operation mandrill is undergoing heat treatment process. Surface heat treatment are performed with case depth hardening is used.

Because of case depth hardening the hardness goes to 60-62 HRC. As this comes in direct contact surface should be hard and inner core will be soft and this will be achieved by case depth hardening process.

2.3 Dober

During design of dober important consideration is this part is completely move inside the chuck body and mandrill, so there dimension will be slightly less than or equal to internal diameter of chuck body portion and mandrill portion where clamp movement is possible. For chuck clamp internal threading of M36 X1.5 is provided so that it should fix to the lathe actuation system. Threads are provided because if any other arrangement use it will restrict the linear movement to some extent but as threading arrangement is use which does not restrict the movement. Outer dimension may be any value but less than 80mm so that it easily moves so we take it as 49mm. length of the internal threading M36 X 1.5 is limited to 30mm only depend on actuation unit. Length of 49 mm outer diameter is taken to be 40 mm because this portion is move inside the chuck body where diameter is 80mm and length of this portion is 40mm. The material select for the dober is EN 8. Turning, drilling, tapping, threading operation is performed on the cylindrical block to get actual shape and size. After all lathe operation grinding operation is performed to get finished surface.

2.4 Chuck clamp

Chuck clamp is part that actually moves forward and backward to clamp the workpiece with chuck. Workpiece is firmly fitted with mandrill by help of chuck clamp. One end of chuck clamp is fitted with dober and other end is moved freely to clamp the workpiece. Chuck clamp is shaft like design with complete solid.

Next to the threaded portion plain shaft like design is provided so it easily moves inside mandrill. Diameter of this portion is 19.50 mm thus it moves freely in portion of mandrill whose dimension is 20 mm internal diameter. Its length is around 60 mm. By inserting lower end of the workpiece firstly in chuck clamp and then rotating workpiece by hand to insert other end of job. This way job is fitted in the chuck clamp.

The material used for the chuck clamp is EN 8. Turning and threading operation is performed on circular shaft to get chuck clamp size.

3. TESTING AND ANALYSIS

After manufacturing of collet chuck it clamp with spindle by nut and bolt arrangement. Some trial is taken so that it will justify correct manufacturing of collet chuck. After successful trial of collet chuck it fix to machine center where actual machining is done. Before noting down reading of new collet chuck, we record old chuck reading and it arranged in the tabular form. After successful trial of the newly manufactured collet chuck, 20-25 readings are recorded for this collet chuck also. Before used of new collet chuck, with the old chuck we taken some readings and this reading are arranged in tabular form as shown in table1. Reading of outer diameter, rib thickness from CNC side I and lug length and total thickness from CNC II side is noted down. After successful trial of new collet chuck, it implement on machine centre and actual production start. With this new chuck numbers of parts are machined and some readings are taken and arranged in the tabular form as shown in table2. Reading of outer diameter, rib thickness from CNC side I and lug length and total thickness from CNC II side is noted down.

Table -1: Observation table for old collet chuck

	CNC I SIDE			CNC II SIDE	
	146.5 +/-0.5	3.5 - 0.15	7.5	11.5 +/-0.2	30.17 -0.2
1	146.65	3.47	7.32	11.56	30.04
2	146.49	3.47	7.47	11.45	30.07
3	146.47	3.5	7.51	11.49	30.11
4	146.57	3.5	7.51	11.48	30.11
5	146.53	3.51	7.49	11.49	30.13

Table -2: Observation table for new collet chuck

	CNC I SIDE			CNC II SIDE	
	146.5 +/-0.5	3.5 -0.15	7.5	11.5 +/- 0.2	30.17 - 0.2
1	146.22	3.47	7.47	11.5	30.09
2	146.26	3.46	7.46	11.53	30.11
3	146.23	3.47	7.47	11.54	30.12
4	146.44	3.43	7.33	11.49	30.09
5	146.47	3.44	7.34	11.48	30.11

Old chuck not maintain accuracy also rejection rates are high. During machining looseness of workpiece increases rejection rates of job. With new chuck rejection rates are decreased drastically and it may be negligible.

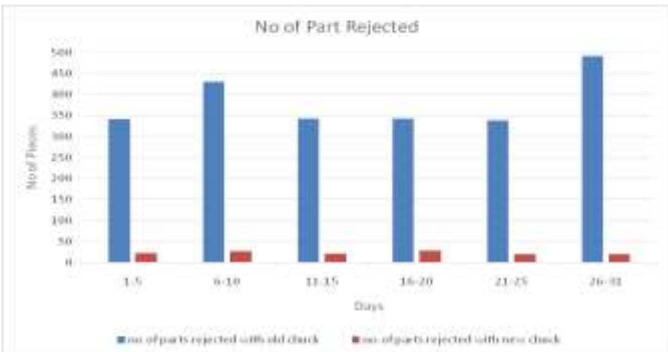

Chart -1: Comparisons of old chuck and new chuck for rejection data

Chart indicates the rejection data of old and new chuck for one month duration. From graph for old chuck weekly on an average 350 pieces are rejected due to machining cause. If we see new chuck column on an average less than 50 pieces are rejected. It shows that use of new chuck reduces rejection drastically and also save the rejection cost. After successful trial of collet chuck and continuous working following result are made

Table -3: Comparison of result of old and new chuck

	old chuck	new chuck
cycle time	40 sec	23 sec
production per shift	850-900 pieces	1100-1200 pieces
average rejection per day	80-90 pieces	4-5 pieces
average rejection cost per day(INR)	1800	100
average rejection cost per month(INR)	50000	3100

For old chuck cycle time is 40 sec and cycle time for new collet chuck is 23 sec, it means cycle time is reduced by 40%. Production per shift for old chuck is average 850 to 900 pieces. After use of new collet chuck production per shift is around 1100 to 1200 pieces. From this we can say that production is increased by 25%. Increased in production is because of reduction in cycle time.

If we see rejection data for the old chuck, it shows that average rejection per day is around 80 to 90 pieces. Then average rejection cost per day for old chuck is 1800 INR and if we see monthly rejection cost is around 50000 INR. Means this rejection cost is huge and this may be financial loss for company.

If we see rejection data for new chuck, it shows that average rejection per day is around 4 to5 pieces. Then average rejection cost per day for new collet chuck is 100 INR and if we see monthly rejection cost is around 3100 INR. As compared to old chuck rejection cost this cost is very less. In percentage point of view rejection of work piece is reduced by more than 90%.

4. CONCLUSION

With use of new collet chuck no job is damaged due to loosening of workpiece during working which happen in three jaw chuck. No chatter marks on finish surface as there is no jaw faces available to hold workpiece. No bending of workpiece due to high gripping force as it does not clamp in between jaws.

Also use of new collet chuck reduces work fatigues of worker which is more in three jaw chuck. Work fatigues reduce as there is no hand movement for clamping the workpiece. Also worker give more interest in work as there fatigues reduces.

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