Design and Optimization of tie Bar Breaking Problem in Injection Moulding Machine

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Abstract— Injection molding machine is one of the oldest and the most widely used processing technique and is playing a dominant role in the development of plastics industry. Thus it is one of the most economical, conventional methods of converting plastic materials into variety simple and complex forms. During the working condition sometime tie bar breaking problem occur in injection molding machine because of (1) Misalignment of the machine (running the machine in an un-parallel condition), (2) Un-even loading of the machine. In last, we give some idea by which this tie bar breaking problem should be optimized.

Key words: Tie Bar Braking, Force

I. INTRODUCTION

The engineering and operation of modern day injection molding machines, it is useful to first look at the not too distant origins of the process. The first injection molding machines were based around pressure die casting technology used for metals processing, with patents registered in the USA in the 1870's specifically for celluloid processing. Injection molding machine is one of the oldest and the most widely used processing technique and is playing a dominant role in the development of plastics industry. Thus it is one of the most economical, conventional methods of converting plastic materials into variety simple and complex forms. It is basically a simple process involving the melting of thermoplastics by heat and filling of the melt into the mold and then hardened by cooling.

Fig. 1: Injection Molding Machine

II. INJECTION MOLDING PROCESS

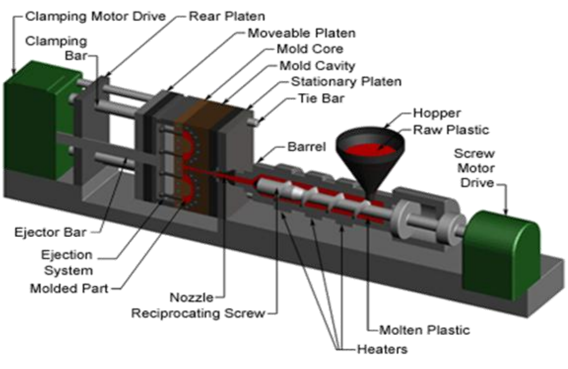

Fig. 2: Injection Molding Process

The high cost of the mold limits its use to components with large shapes and size. From the above process it is clear that the injection molding machine have four basic parts namely

the clamping unit has two basic functions to perform.

1) Clamping unit
2) Injection unit
3) Cooling unit
4) Ejection unit

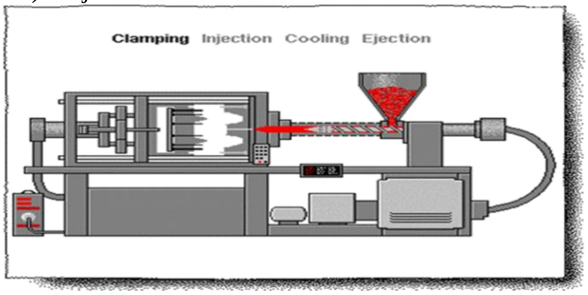

Fig. 3: Claming unit

1) To provide the force required to hold the mold closed.
2) To perform mold closing movement and in addition to perform the task of mold opening and ejector operation.

- Types of clamping units :

1) Straight hydraulic clamping unit
2) Toggle clamping unit

A. INJECTION UNIT

A basic function of all machines injection units is

A) Melting and preparation of the polymeric rising.
B) Pressurizing and feeding the molten resin into the mold controlled conditions.

Therefore the injection unit is the most important parts of the machine the screw rotation will convey and heat the material by mechanical shear.The screw is also acting as a high cost of the mold limits its use to components with large shapes and size. From the above process it is clear that the injection molding machine have three basic parts namely plunger to inject the material into the mold.

B. COOLING UNIT

The screw is held in the forward position for a set period of time,usually with a molten cushion of thermoplastic material in front of the screw tip such that a holding pressure may be maintained on the solidifying material within the mold¸ thus allowing compensating material to enter the mold as the molded parts solidifies and shrinks.

C. EJECTION UNIT

When the cooling phase is complete the mold is opened and the molding is ejected. This is usually carried out with ejector pins in the tool, which are cooled via an ejector plate to a hydraulic actuator, or by an air operated ejector valve on the face of the mold tool. The molding may free fall into a collection box or on to a transfer conveyer may remove by an automatic robot.In this latter case the molding cycle is fully automatic. In semi-automatic mode, the operator may intervene at this point in the cycle to remove the molding manually. Once the molding is clear from the mold tool, the complete molding cycle can be repeated.

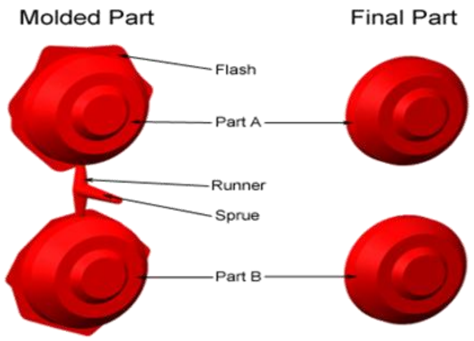

Fig. 4: molded part to final part

III. CONTROL PARAMETERS OF INJECTION MOLDING MACHINE

Some types of material, such as thermoplastics, the scrap material that results from this trimming can be recycled by being placed into a plastic grinder, also called regrind machines or granulators, which regrinds the scrap material into pellets. Due to some degradation of the material properties, the regrind must be mixed with raw material in the proper regrind ratio to be reused in the injection molding process.

A. Barrel temperature:-

This is the temperature of the plasticization barrel, which is set on the control, zones and which is recorded by thermocouples and controlled by pyrometers.
As the heat conducted by barrel and the shearing due to screw rotation heats the polymer, the barrel temp is not the same as melt temperature. So the temperature of each zone and the screw rpm are to be set in such a way, that we get a homogenous melt at correct and temperature.

B. Injection Speed:-

By 'Boost' we understand the maximum injection speed. By switching over to 'Boost' we inject the melt using two or more pumps until switch is depressed this cuts out the other pumps leaving the small pump only to complete the injection phase the same pressure. The injection speed should be adjusted in such a way that the melt flows to every part of the cavity before it gets colder or frozen.

C. Injection Pressure:-

Injection pressure is the pressure built up in the material accumulated in front of the screw during injection. Pressure is required to push the farthest point in the mold through the passage of different wall thickness. The screw in its advance stroke applies this pressure. It depends upon melt viscosity, wall thickness of flow in the mold, nozzle head hole diameter, length of flow at melt etc.

D. Hold on pressure:-

It is also called reduced injection pressure. It is the pressure set to act on the material after volumetric filling has been completed. It is utilized to compensate for shrinkage due to cooling. Hold on pressure should be such that is should prevent the back flow of the melt from the cavity through gate to nozzle and it should be maintained fill the gate freezes. It influence weight, shrinkage and warpage.

E. Injection Time:-

It includes the time to complete the injection stroke and hold on pressure time. The injection time depends upon the shot weight injection speed, size of runner, gates etc. increase in injection time results in increase in weight of molded part to a certain extent.

F. Back pressure:-

For the satisfactory plasticization of certain material it will be necessary to reduce the screws plasticizingcapacity by the addition of also increase. It helps in colour mixing and increases the melt homogeneity.

G. Suck Back:-

To prevent the open nozzle drooling after refill, this system is provided. As soon as stroke is overs the screw will be pulled back to the adjusted distance and thus prevent drooling.

H. Screw R.P.M.:-

Rate of plasticization is proportional to screw r.p.m. The heat generated due to shearing of polymer is also proportional to screw r.p.m. Refilling is done during cooling time lower r.p.m. will cause extension of cooling time and lower production rate. But higher screw R.P.M. will increase the shearing and melt temp and give rise to black speaks due to burning of material.

I. Cooling Time:-

The cooling time is the period immediately following the injection phase and preceding the mold opening phase. It is thus the overall time available for the molded component to cool in contact with the mold under the action of the full clamping force. Normally cooling water is circulated after the mold attains certain recommended temp. It depends upon the thermal conductivity of mold material distance between cooling channels and mold surface, polymer, enthalpy, rate of flow of cooling water.

J. Mold Temperature:-

The mold temperature is require to be maintained at a particular temperature approximately at 30-175 c depending upon the polymer, to provide good surface finish and controlled shrinkage, molds should have channels through which heating or cooling medium flows. It will depend upon flow rate and pressure of cooling medium inlet temperature of the cooling medium melt temperature and cooling time.

IV. REASONS FOR TIE BAR BREAKING PROBLEM

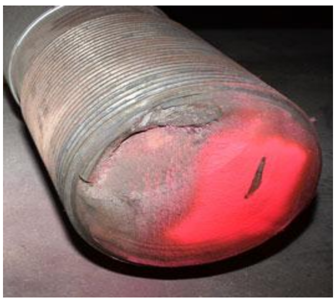

Fig. 5: Damage tie bar

Most experts agree that tie bars break at a particular location most commonly due to corrosion or a pre-existing metallurgically "bad area" in the bar including cracks, inclusions, and improper alloying. While this tells you why it broke a particular location it does not explain "why it broke". When a die cast machine or injection molding press breaks a tie bar, virtually always only one tie bar breaks; it broke because it was loaded beyond it capacity. Why was only one tie bar loaded beyond its capacity? Consider the following possibilities:

V. Misalignment of the Machine (Running the Machine in an Un-Parallel Condition) Commonly Caused Through

- Purposefully running the machine "out of square" to compensate for a poorly designed die or mold, i.e. the die does not exert even pressure on the platens when set because of the location of the cavity (cavities) in the die.
- Purposefully running of the machine out of square to compensate for a die in poor condition, i.e. die does not exert even pressure because the die is no longer "square" and the machine is purposefully mis-adjusted to compensate for this condition. A die that is not parallel is going to wreak havoc with your machine in every way; parallelism of your die is critical to the life of the mechanicals of your die cast machine.
- The die cast machine or injection molding press is not level, this is an often overlooked problem. This condition can cause the machine to run out of square causing linkage to exert uneven pressures on the tie bars and causing breakage of a bar.
- Your die cast machines is not well secured to the floor, this can create a condition in which the machine "seems to be level" when checked statically but once the machine opening and closing it "looses" it level condition.
- Poor maintenance; everything mechanical in a die casting machine or injection molding machine including the machine linkage, tie bars, tie bar nuts and platens are wearing; as an example the threads on the die height nuts actually wear from the continuous loading and unloading of the machine, these worn threads cause "slop" between the tie bars threads and the and tie bar die height nut threads. Because in real life machine loads are never perfect, mechanical areas of the machine wear at different rates causing the machine to be "out-of-square" creating un-even loading. Machines should be checked for sureness using a "squaring block" or "test ring" on a regular basis and adjusted as necessary.
- Purposeful mis-adjustment of the machine to allow the die to "spit" in a particular way.

A. Un-even loading of the machine, commonly caused by:

- Purposeful "overloading" of the machine, you have a chance to get a job and die that your engineers says should be run in an 1100 ton machine but you have time available in 1,000 ton machine so you run the machine beyond its limit.
- Coining in the platens does not allow the die to be set properly. You can have a new linkage and a properly squared machine but coining will keep the die from being set correctly.
- Another common cause for uneven loading is that the location of the die in the die cast machine is not correct because the exact or "ideal" shot hole location (shot position) does not exist on a particular machine, i.e. the tool was built to be run at 250 mm (9.84 inch) below center but the available machine only has a 9 inch (228 mm) shot position so you "make due" with what you have available.

B. Injection molding machine tie bar maintenance

High quality injection molding machines required good machine design,good machine parts,good assembling and good balance.Injection machine tie bars are one of the main part of injection molding machines.Injection molding machine tie bar maintenance is very important.

Injection molding machines should be running under balance condition,or the injection molding machines could not work stably and the parts are easily broken.Before the machine starts running,we have to inspection the machine first,check the balance,check the oil and lubricationtighten the screw,etc.

VI. Optimization and Solution of Tie Bar Breaking Problem

For minimization of tie bar breaking it must be needed, the load is equally distributed among the four tie bar.If any-one tie bar get more load then other three tie bar there is more chances to damage that one.

Following point can help in reduce the tie bar breaking problem:

- Moving platen and stationary platen need compulsory parallel.
- Also surface of the mold core and cavity need parallel.
- At working condition of machine strain is produce in the tie bar it must be equal on four

A. Complete Tie-Bar Squareness Measurements :

With the L-743's built-in squareness, (each laser plane is square to each other) measuring the perpendicularity of the tie bars to the platens is a simple task. In fact, with just two setups you can measure all four tie-bars for squareness in two axes. And since the data is live, squareness errors can be fixed without changing the setup. Given that the laser has a range of 100 feet (30.5 meters) in radius, even the entire length ofthe largest injection molding machines can easily be measured for squareness.

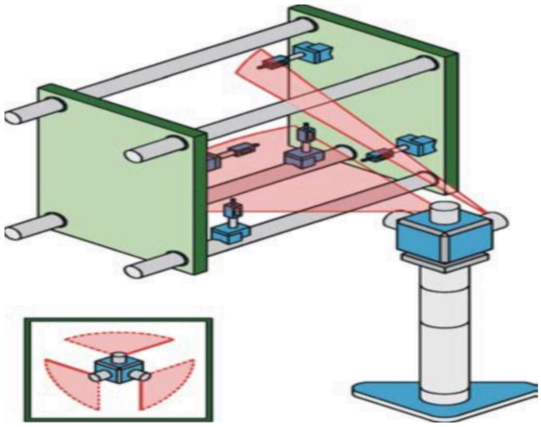

Fig. 6: Tie bar squareness measurements

The process starts by setting up the laser to 5 points as described above. To measure the squareness, for example, of the two lower tie bars to the fixed platen in the vertical direction, a target would be zeroed at a point on each tie bar closest to the fixed platen. Since the vertical laser plane has been bucked in to the fixed platen, the horizontal plane is perpendicular to the fixed platen. After zeroing the target, it is traversed along the tie bar. A "+" reading indicates the tie bar is sloping "up-hill" relative to the platen; a "-" reading means it is sloping "downhill". A bubble level on the target base keeps the target at top-dead center of the (round) tie bar.

To measure "horizontal" squareness of the same tie bar, the target can then be placed on the tie bar horizontally and zeroed to the 3rd (vertical) laser plane. As the target is moved along the tie bar horizontally (again a bubble level on the target base keeps the target at top-dead center), any deviation from the zero point is a measure of horizontal squareness of the tie bar.

The same method is used to measure the squareness of all four tie bars; however, it usually takes two setups to measure all the tie bars for squareness.

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NO.	Procedure	Timeline (minutes)
1.	Set the laser on an instrument stand either outside the machine or inside the machine as shown (Laser Position #1). Position the laser so the laser plane (LP) #1 is at a sufficient height to allow measurement of the upper tie bars for squareness. Ensure that there is sufficient room between the lower left tie bar and LP#3—75 mm to 300+ mm is the correct range.	5-10
2.	Place a single-axis target (A-1519, A-1519HR or A-1533) in the lower left corner of the platen and zero. Mark the spot for reference purposes, and then move this target to the upper left side of the platen. Place a second target on the same point in the lower left corner of the platen and zero the display.	3-5
3.	Adjust the pitch axis of the L-733/743 until the same reading appears on both targets. This means the laser is now parallel to these two points (shown on left side of the Front View). Re-zero both targets.	1-2
4.	Move one of the two targets (without changing the zero point) to the lower right side of the platen. Adjust the yaw axis until the target at this location reads zero. Re-measure the other points to ensure that they all read zero. The laser plane is now parallel to the fixed platen.	
5.	Mount a target on the lower left tie bar and level using the built-in level vial on the target base. This keeps the target at top dead center. Adjust the target height until it reads LP #1. Zero the target and mark the reference point. Move the target the lower right tie bar. Repeat this procedure with a second target, placing it on the same reference point on the lower left tie bar where the first target was zeroed.	3-6
6.	Adjust LP#1 using the roll axis in the laser base until both targets read the same number, making the laser plane parallel to the two lower tie bars.	1-2
7.	Now the laser is ready to measure parallelism and squareness of two of the four tie bars. Note: Skip Steps 5 and 6 if tie-bar squareness is not desired.	
8.	To measure platen parallelism, assuming the moveable platen is within 1 meter of the fixed platen, place a target in one corner of the moveable platen. Add or remove rods from the targets so that the length of the target height allows it to read the laser plane.	1-2
9.	Move the target to the other three corners and note the readings. Any deviation from zero is a measurement of out-of-parallel condition of the moveable platen to the fixed platen. Since the readings are live, the target (or targets) can be left on the platen while it is being adjusted to bring it into alignment.	1
10.	Since all three laser planes are perpendicular to each other, the laser is also now set up to start measuring tie-bar squareness. Note that the laser cannot measure all four tie bars for squareness with one setup	
11.	To measure squareness of the lower tie bar to the platen in the pitch axis, (as defined by looking into the end of the tie bar) use the target that set up LP#1 (which should still be reading zero). Move the target the other end of the tie bar, where its reading will indicate the squareness. If it reads zero, then it's square to the platen. If not, then the amount shown on the readout is how much either the platen or the tie bar needs to move to bring it into specification.	1-2

	Again the reading is live, so the target can be left in place while the adjustments are being made.	
12.	Move the target along the tie bar in small increments to measure the tie bar for straightness. Note the readings as the target is moved.	
13.	To measure the tie-bar squareness in the yaw axis (as defined by looking into the end of the tie bar), set up a target at the 3 o'clock position on the tie bar (see Front View). The level on the target base can be moved to the side of the base to keep it at top dead center.	1-3
14.	Adjust the target until it picks up LP#3 and zero the target. As in Step 11, move the target to the other end of the tie bar to measure the squareness. If the reading not zero, it is not square. At the same time, the upper tie bar can be measured for squareness in the same yaw axis with the same setup.	1-3
15.	The upper tie bar squareness in the pitch axis can be measured by turning the target up side down, picking up LP#1 and following Step 11. This also measures the parallelism of the upper tie bar to the lower tie bar in the pitch axis. Similarly, the upper and lower tie bars can be measured for parallelism in the yaw axis by using LP.	2-4
16.	To measure the two right-hand tie bars, move the laser to Position #2 and repeat Steps 1-6 to make the laser planes parallel to the same reference.	5-10
17.	Repeat Steps 11-15 to measure the squareness of the two right-hand tie bars.	3-5

B. Hard chrome plating Specification

This is the most widely used specification for hard chrome plating for dynamic services
This specification has the following general requirements:
1) Proper cleaning of parts prior to plating.
2) Shot peening to assure better bonding with greater fatigue strength.
3) Baking at 375°F (190°C) immediately after plating to reduce hydrogen embrittlement, increase fatigue strength and reduce cracks.

Fig. 7: Chrome Plated tie bar

1) STRESS & FATIGUE

Electroplated hard chrome has been used in high wear and erosion situations where temperature changes are evident because of its coefficient of thermal expansion and high oxidation resistance. When subjected to a cyclic temperature setting, the expansion and contractions of the material lead to crack initiation and growth. The hard chrome plating has a coefficient of thermal expansion that will minimize crack initiation and growth The oxide layer that forms becomes brittle over time and highly stressed. This results in its possibility to flake off, taking with it some of the chromium plating coating required to protect the base material.

2) THERMAL EFFECTS

Hard chrome plating does handle thermal changes well due to its high thermal conductivity value.A localized increase in friction may result in the increase of material or coating temperature. The chrome plating's ability to effectively dissipate this heat through the material and surroundings will reduce the risk of its failure by a decrease in its hardness and excessive wear.
cycling. Studies performed on various hard chromium coatings have been performed with uncoated steel used as a control to test and understand the effects of thermal fatigue on the coating with respect to its hardness. Reasons for the change in hardness due to thermal fatigue were speculated to be due to a loss of valuable hydrogen from the coating and thereby causing a phase change and reducing the hardness

3) ADVANTAGES OF HARDCHROME PLATING:

- Very good adhesion to base material.
- Improves and maintains surface finish.
- Close dimension control after coating.
- Increases hardness of surface.
- Low coefficient of friction.

C. Tie Bar With Support Roller Bearing

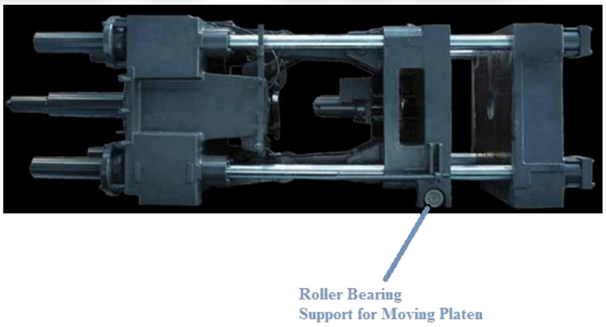

Fig. 8: Tie Bar With Support Roller Bearing

Tapered roller bearings have excellent radial and good thrust load carrying capabilities. They are good for high speed and high accuracy but poor for misalignment. They too are commonly mounted on both ends of the same shaft.Tapered roller bearings are used extensively in automotive design.

	Radial ball bearing	**Angle contact ball bearing**	**Cylindrical roller bearing**	**Tapered roller bearing**
Radial load	Fair	Good	Good	Good
Thrust load	Fair	Good	Fair	Good
Combined load	Fair	Good	Fair	Good
High speed	Excellent	Excellent	Excellent	Good

High accuracy	Excellent	Excellent	Excellent	Good
Low torque	Excellent	Fair	Good	Fair
Misalignment	Good	Poor	Fair	Fair

VII. DESIGN OF TIE BAR

Most PIMMs with tie bars have four of them, except small machines below about 20 tonnes, which have two. Together, their tension force shold the mould halves together against cavity pressure during injection. If the tie bar tensions are even, the stress in each of them is given by,

stress = clamping force * 1000/(3.14*(d2/4)*4),

= clamping force * 1000/(3.14*d2),

Where,

stress is in kg/mm2

clamping force is in tonnes,

diameter d in mm.

High tensile steel has a breaking stress of more than 90kN/mm2. Mild steel has a breaking stress of 20kN/mm2. A tie bar breaks if its stress exceeds the breaking stress.

Parameters	**Unit**	**Sprint 250**	**Sprint 650**	**Sprint 1100**	**Sprint 1600**
Injection Unit		1480	4800	6270	8800
Screw dia.	mm	60	100	110	110
Injection pressure	bar	2156	1520	1500	1750
Stroke volume	Cm^3	690	3180	4181	4560
Screw stroke	mm	280	405	440	480
Max. injected weight	gm	751	3021	3972	4334
Injection rate	cc/s	336/319	700	680/710	585/605
Plasticizing rate	g/s	70	140	165	165
Screw speed	rpm	240	140	130	130
L/D ratio		22	22	21.8	21.8
Heating capacity	kW	24.48	53.4	68	68
No. of heating zones	no.	4	6	6	6
Closing Unit					
Closing force	kN	2500	6500	11000	16000
Mold opening stroke	mm	700	1750-1250	2200-1600	2450-1800
Mold height	mm	275-625	450-950	700-1300	750-1400
Distance bet^n plates	mm	1225	2200	2900	3200
Distance bet^n tie bars	mm	640*640	950*950	1470*1120	1800*1400
Clamping plates	mm	970*970	1430*1425	2050*1700	2450*2050
Ejector force	kN	75	200	200	265
Ejector stroke	mm	150	200	250	300
General Data					
Pump drive	kN	37/24.6	77(50+22)/41.5()37.8+3.7	77(55+22)/41.5(37.8+3.7)	77(55+22)/41.5(37.8+3.7)
Total conn	kW	61.48/49.1	130.4/94.9	145/109.5	145/109.5

ected load					
Oil tank capacity	Lit	550	1200	1200	1600
Hopper capacity	Lit	65	200	200	200
Machine weight	ton	14	36(25+11)	72(60+12)	77(65+12)

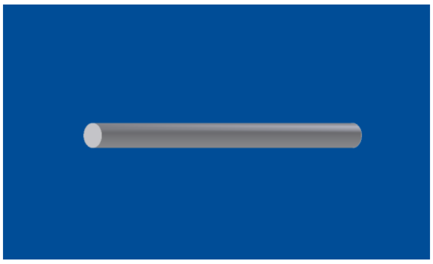
Fig. 9: Model of Tie Bar

Sprint Model No.	**Total Load (kN)**	**Stress (N/mm^2)**	**Diameter Of Tie Bar (mm)**
Sprint 250	2500	770	96.46
Sprint 650	6500	770	155.54
Sprint 1100	11000	770	202.35
Sprint 1600	16000	770	244.04

In conclusion, only perfect machine and mold alignment can ensure the quality of the parts. This will also greatly extend the lifetime of tool and mechanical aspects of the machine.

VIII. CONCLUSION

It is concluded that Injection machine tie bars are one of the main part of injection molding machines.In conclusion, only perfect machine and mold alignment can ensure the quality of the parts. This will also greatly extend the lifetime of tool and mechanical aspects of the machine.

REFERENCES

[1] J. Michalska and D. Szewieczek, “The improvement of the quality management by the activity-based costing”, Journal - Journal of Achievements in Materials and Manufacturing Engineering 21/1(2007) 91-94.
[2] Mihail Aurel Titu; Constantin Oprean and Daniel Grecu, Proceeding of the international multiconference of engineer and computer scientist 2010 Vol III, IMECS 2010, Hong Kong, March17-19, 2010.
[3] Maharjan, Shyam K., Implementing the 5S Methodology for a Graphic Communications Management Laboratory of University of WisconsinStout May, 2011, pp 20-31
[4] Taiichi Ohno, Toyota production system, Productivity press, 1988.
[5] S.K. Ho, TQM an Integrated Approaching – Implementing Total Quality through Japanese 5S and ISO 9000, Kogan Page, London, 1996.