DESIGN & FABRICATION OF TOOL FORCE DYNAMOMETER FOR TURNING OPERATION

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Abstract: Cutting forces plays a vital role in machining process as they provide useful information not only for the work done but also for understanding the mechanics of machining process. Design cutting tool (Material & Geometry) and selection of proper cutting parameters. Machining is a process design to change, size, shape and surface of material removal of material by straining the material to fracture with a help of single point cutting tool, while operation various. Forces produce in machining lathe tool dynamometer can evaluate cutting forces induced. The sensing system measures the deflection in load cells and these signals are modified in to other quantity and compared in the form of forces on display system. A novel geometrical design of the dynamometer structure allowed the standard tool shank of the turning operation to be easily changed without altering the sensor system. The developed dynamometer can perform the cutting force measurement up to 2.0 kN. This report is focus on geometrical design, mathematical and design analyses that are significant role in force sensor developed and present an application of low cost sensing method in turning process. In present work, on attempt has been much to design and fabrication of tool force dynamometer for turning operation on basis of the technological design dedicated tool force design is being fabricated.

Index Terms - Force measurement, Load cell, Dynamometer, Optimization, Analysis.

I. INTRODUCTION

The knowledge of cutting forces developing in the various machining processes under given cutting factors is of great importance, being a dominating criterion of material machinability, to both: the designer-manufacturer of machine tools, as well as to user. Furthermore, their prediction helps in the analysis of optimization problems in machining economics, in adaptive control applications, in the formulation of simulation models used in cutting databases. These cutting forces are not only important for measuring the work done but it's an essential requirement for machining process as theses cutting forces are directly related to determine tool material, tool design, surface finish and also helps in predicting power consumption, vibration and machine part design etc.It is for this reason these cutting forces able us to understand the mechanics of cutting process such as it helps in developing force models, work piece material characterization and machinability tool geometry optimization, proper selection of cutting parameters, chips formation, vibration detection and cutting process control etc. Experimentally cutting forces measurements can be accomplished either by direct or indirect method. An indirect method of force measurement is less accurate as it utilizes the power rating ratio of the machine tool to measure the cutting forces during machining process, while a force dynamometer is used in direct force measuring system in which either tool i.e. in turning or work piece i.e.in drilling, milling and grinding etc. is mounted on the force dynamometer which measures the cutting forces generated during machining by producing proportional electrical signals (voltage) in response elastic deformation. Two types of force transducers are normally used in design and fabrication of force dynamometers; it may be either load cell or piezo-electric material. Load cells are preferred as they provide good response to deflection produce at suitable spots on flexible mechanical component. In present work, an attempt has been made to design a tool force dynamometer, which is capable of measuring two force components in turning operation with various work piece under different cutting parameters is being fabricated. Furthermore, the actual model of dynamometer will be experimentally tested by performing static calibrations and cutting tests.

II. AUTHOR GUIDELINE FOR MANUSCRIPT PREPARATION

A. Acronyms and Abbreviations.

III. EXPERIMENTAL SETUP

A two force components tool force dynamometer for turning application in lathe was design and fabricated. The schematic representation of the dynamometer is shown in figure one. This type of dynamometer consist of two strain gauge based load cells mounted on its base plate that are capable of measuring cutting & thrust forces induced during turning operation. The dynamometer was further connected to multi-component digital force indicator to measure the resulting forces from the deflection of load cells. The experimental setup of tool dynamometer on cross-slide of lathe machine is as shown in figure 1.

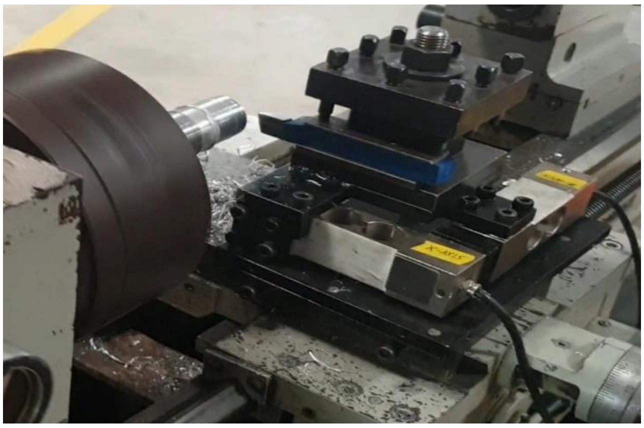

figure 1: arrangement of tool force dynamometer.

table 1: specification of equipment use

Equipment	*Specification*
Lathe Machine	*2.20k Watt, 3 Horse Power, Horizontal axis lathe machine tool, 4 feet*
Dynamometer	*Two component force dynamometer for turning process*
Load Cell	*Strain gauge based, 0-2000 N*
Workpiece	*Aluminum, Mild Steel*
Cutting Tool	*Single Point Cutting Tool (H.S.S.)*

IV. Design & Construction Of Dynamometer For Turning Process

4.1 Design Considerations for Dynamometer

While designing, care has to be taken in cases where turning operations are involved. Turning machines such as Centre lathes and automatic lathe, allow components that are cylindrical to be used. Design the parts in such a way that the complete machining of the part can be completed in one machine itself. Other requirements are concerned with dynamometer structure; i.e. it should have minimum cross sensitivity in addition high natural frequency with wide frequency response is also desirable. It should have high stiffness and low mass, ensuring 100 percent transmissibility of force by its very high natural frequency. This feature will also enable the recorded force to be unaffected by the exciting vibration due to machining process itself. It should be capable of indicating individual force components without any cross effect, while measuring such forces simultaneously. Furthermore the material selected for dynamometer must have high heat of conductance and resistance to corrosion and should withstand vibration during machining. Moreover, the local deformation under the load should be conforming to that of load cells mounted on dynamometer outer surface. The design should not have interrupted surfaces because they are likely to cause the impact forces.

4.2 Dynamometer Construction

4.2.1 Mounting of Load Cell in Dynamometer

After selecting proper orientation for the load cells on the dynamometer, next step is to mount theses load cells on the dynamometer. The selection of clamping surfaces should be done in such a way that clamping of that part can be done easily in the shortest possible time with little skill. The selected surface must have enough rigidity such that no deformation of the component takes place under the clamping forces. After this Allen bolt and spacer plates are used to mount load cells on selected surfaces of the force dynamometer. The tool holder type dynamometer is then mounted on tool post of horizontal axis lathe machine to measure the cutting forces as a response from a local deformation produced in tool holder during metal cutting in turning.

4.2.2 Dynamometer construction.

In order to put the analysis of the metal cutting operation on a qualitative basis, certain observations must be made before, during and after a cut. In particular for turning process the results are analysed, leading to an appraisal of the current status of the cutting force measurements with respect to feed rate, speed and depth of cut cutting force have been measured by using the lathe tool dynamometer. Figure 4.26 shows the project overview and manufacturing flow chart is given for the tool force dynamometer.

The first and foremost factor is idea generation and objective of the project. To design the tool force dynamometer the concept of designing and idea screening help to provide the initial stage of designing and problem identification. After the idea screening the next stage is to design all necessary components of projects. In designing of component, it is must to determine the factors to be considered according to parameters. In Detailed design analysis certain parameters (i.e. Material Selection, Design Objective, Load Specification, Calculation check, Design Drawings, Cost Estimates) would be consider for the validation of design. If the design of component is not compatible with required parameters then it should be modify accordingly. After selecting the suitable material next stage is to prepare process plan. In the process planning certain tasks, like to select the proper production line to dispense of the particular component to particular machine station are included. Material flow to the workstation would be done from the storage. After the selection of proper production line material under goes to cutting process, in which the material will be cut in specified dimension of components.

Raw material will further go for the machining after the cutting process. Raw material sheets of components will machined with suitable manufacturing methods (i.e. shaping, milling, drilling, grinding, and turning). Manufactured and machined components will further go for the inspection and quality check. At this stage, if the manufactured component is as per the dimensions and specification then it passed the inspection and further give to assembly department else part or component should require the re-production or re-designing to resolve the problem.

All the manufactured components gather at the assembly line point. In assembly line, all the components will be assembled together and final working model will prepare. Furthermore, Tool force dynamometer validate with the number of experiments. After completion of experimental validation, the next stage would be preparation of result according to experiments. Experiment should be done with Taghuchy’s orthogonal array approach. The result should be prepared according to different method available for the force measurement to validate and compare the result and error percentage with the other methods. The conclusion will be prepare based on the experiment result. After the device verified according to standards and conclusion is made accordingly the next step should to prepare the concept of the project report. Project report must include all the methodology and validation processes from the initial process to final process of the project.

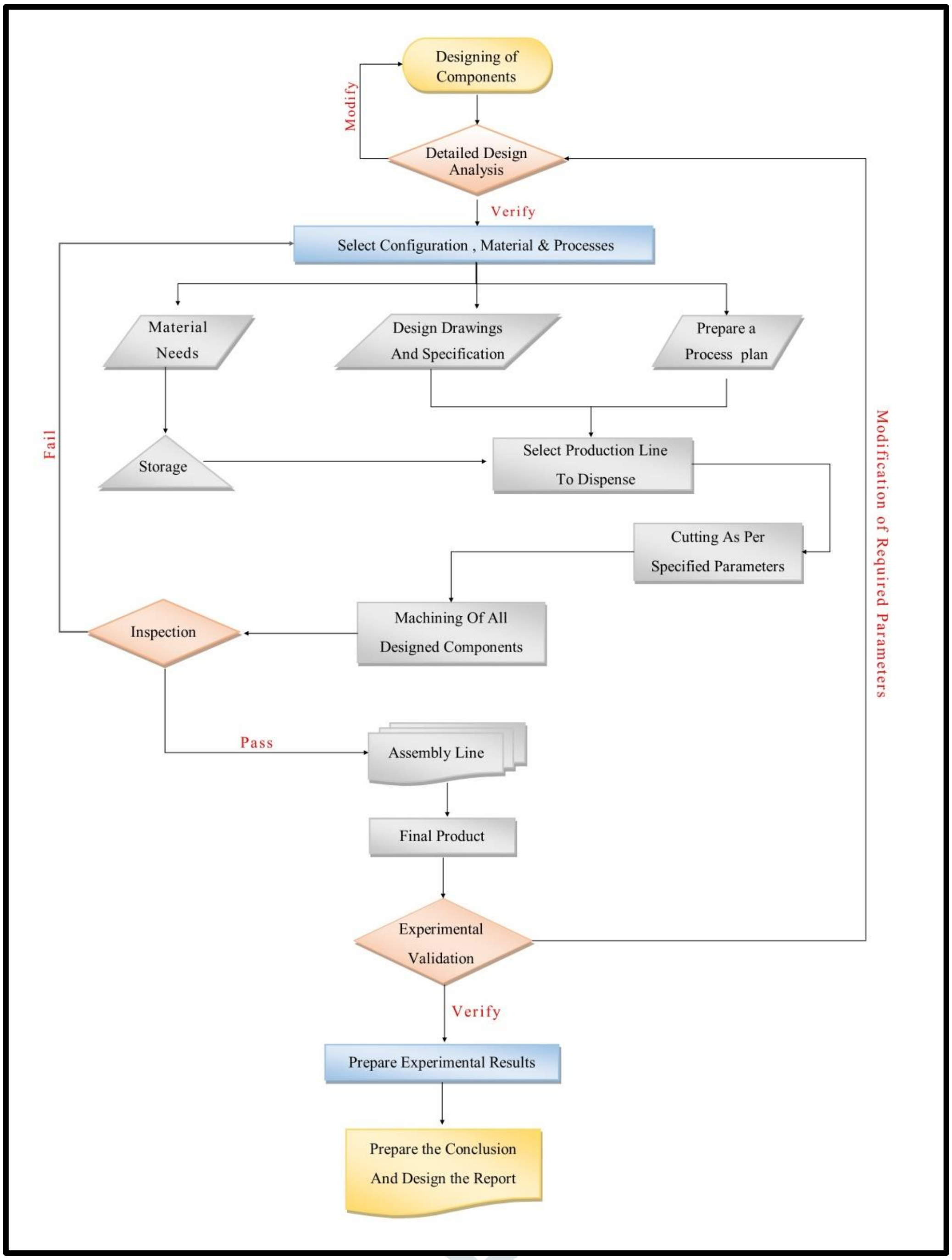

figure 2: project overview & manufacturing flow chart.

V. Experimental Analysis & Validation

5.1 Force Measurements

For measurement of induced thrust and cutting forces tool dynamometer was used as shown in figure 1. Horizontal axis lathe machine tool was used to perform all the experiments. Specifications of all other equipment used in current experimental work are given in table 1.

5.2 Experimental Procedure.

In force analysis with Lathe Tool Force Dynamometer, Initiated forces will be observed and calculated using the dynamometer instrument and forces visualised on multicomponent digital force indicator. At this point the analysis is limited to two dimensional or orthogonal cutting, which is simpler to understand as compared to the complicated three-dimensional cutting process. Thrust force (Ft) and cutting force (Fc) would be analysed using the tool force dynamometer. For the accurate result

rigidity and sensitivity of tool force dynamometer effected. Therefore, clamping and mounting of the dynamometer should be done in a proper way on the lathe cross-slide.
In experimental setup, Tool force dynamometer mounted on the cross-slide of the lathe machine. Dynamometer clamped with cross-slide with L-shaped plates and Allen bolts. Multicomponent digital force indicator connected with two individual load cells for force analysis in two directions. Arrangement of tool dynamometer on lathe machine cross-slide is as shown in figure 1. The selected variables for the experiments are mainly speed, feed and depth. The following Table 2 lists all the parameters and their magnitudes used in force measurements in turning of aluminum and mild steel. Machining is done for dry case only.

table 2: different parameters used for force measurements.

SR. No	*Parameters*	*Magnitudes*
1	*Cutting speed (rpm)*	*75,300,750*
2	*Depth of cuts(mm)*	*0.3,0.6,0.9*
3	*Feed rates (mm/rev)*	*5 mm*
4	*Lubricants*	*Dry cutting*

VI. Validation of Experiments

table 3: experimental results for level 2 design.

Dial Indiacator							
Sr. No.	*Speed (RPM)*	*Feed (mm/Rev)*	*Depth (mm)*	*Material*			
				Al.		*M.S.*	
				Fc (N)	*Ft (N)*	*Fc (N)*	*Ft (N)*
1	*75*	*0.5*	*0.3*	*10*	*36*	*27*	*37*
2	*75*	*1.5*	*0.9*	*18*	*92*	*95*	*268*
3	*750*	*0.5*	*0.9*	*35*	*59*	*42*	*93*
4	*750*	*1.5*	*0.3*	*25*	*46*	*32*	*69*
Dynamometer							
Sr. No.	*Speed (RPM)*	*Feed (mm/Rev)*	*Depth (mm)*	*Material*			
				Al.		*M.S.*	
				Fc (N)	*Ft (N)*	*Fc (N)*	*Ft (N)*
1	*75*	*0.5*	*0.3*	*16*	*50*	*18*	*31*
2	*75*	*1.5*	*0.9*	*60*	*165*	*169*	*272*
3	*750*	*0.5*	*0.9*	*50*	*127*	*56*	*155*
4	*750*	*1.5*	*0.3*	*75*	*205*	*20*	*60*

In order to evaluate the performance of force measurement using strain tool dynamometer in a real turning operation, machining tests performed using the cutting parameters as given in Table5.7. Therefore, for better results and understanding relations between cutting parameters and force various graphs should be constructed using different relations of speeds, feed rates and depth of cut according to specific materials and forces.

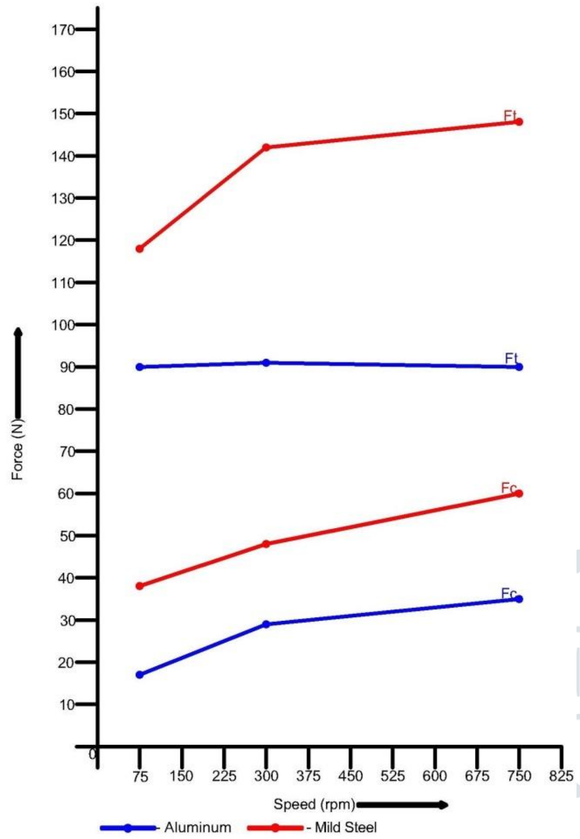

figure 3: dial indicator graph [force v/s speed]

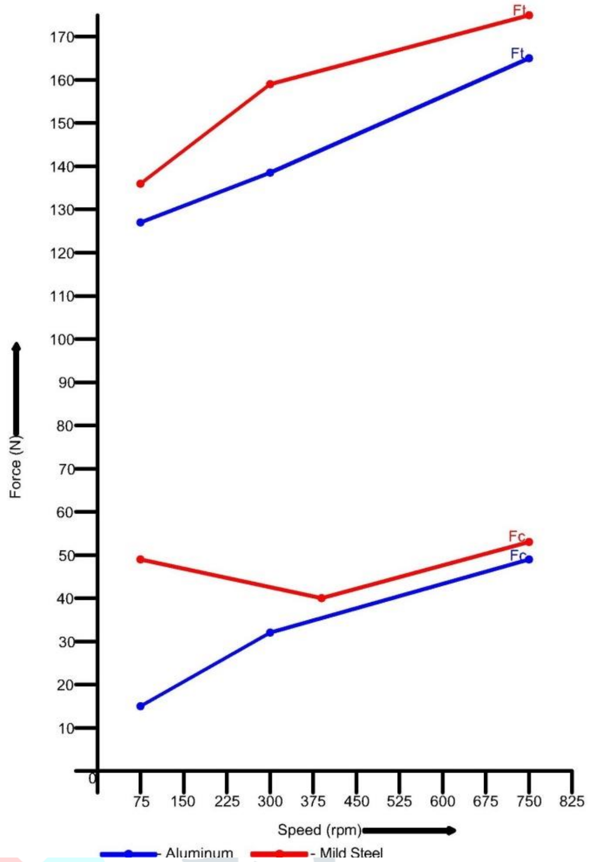

figure 4: dynamometer graph [force v/s speed]

Fig. 3 Dial Indicator Graph [Force □Speed] Fig.4 Dynamometer Graph [Force □Speed]

To understand the influence of cutting parameters on the forces generated in turning operation, Line graph of force vs. speed given in figure 3 & 4. Construction of graphs should done according to observations of thrust forces (Ft) and cutting forces (Fc) with respect to specified speed. It is observed form figure 3 that cutting forces (Fc) generated in the tools showing increasing trend towards speed for both the workpiece materials. On the other side, from dynamometer graph shown in fig 4, it clearly observed that cutting forces induced in aluminium increasing with increasing in speed but in mild steel until one point cutting forces are decreasing with increasing in speed and after the optimized point forces will increase with increase in speed. Results for the thrust forces are as same as cutting forces as shown in fig 3 & 4.

Therefore, results in the dial indicator method consist inaccurate results compare to dynamometer results. Dynamometer results are more desirable according to control factors and quality characteristics.

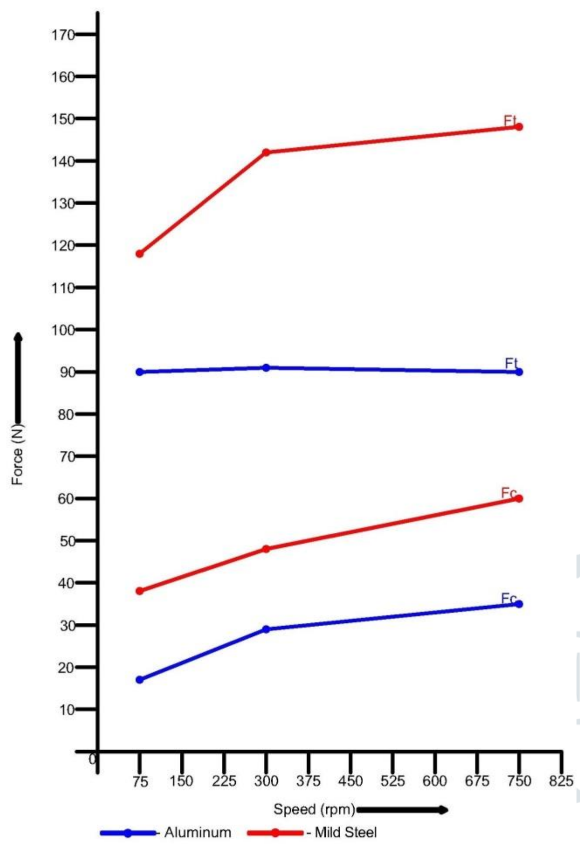

figure 5: dial indicator graph [force v/s depth of cut]

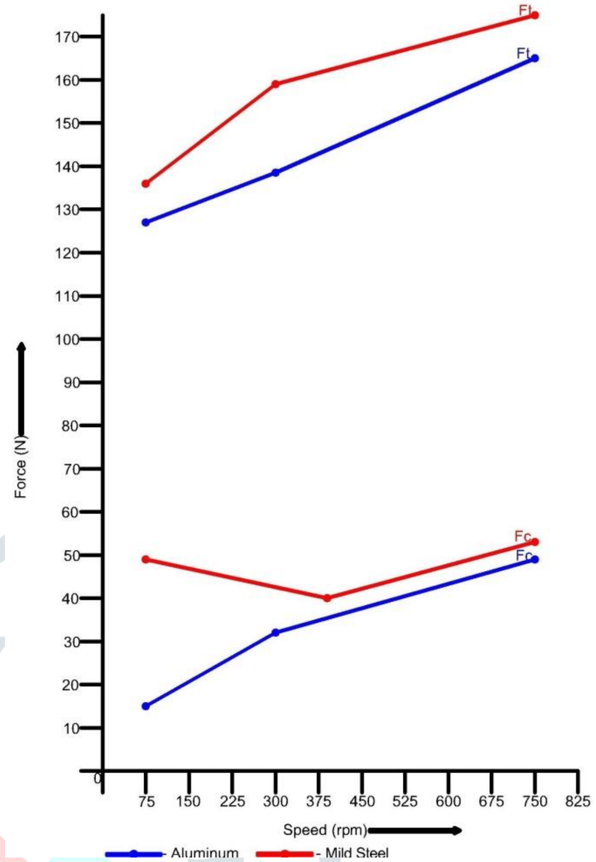

figure 6: dynamometer graph [force v/s depth of cut]

It was observed experimentally that the cutting forces increase with increase in depth of cut and feed rate values so that they have direct influence on the cutting forces for all specified cutting speeds. From the figure 5 and 6. As per observation recorded, the cutting forces and depth of cut is directly proportional to cutting forces. All the analysis is shown in figure 5 and 6 which shows that on increasing the depth of cut leads to increase in cutting and thrust force i.e. approximately linear. In addition, cutting forces depend upon feed rate of tool so the cutting forces increase as feed rate increases.

The records obtained from the two-component tool forces dynamometer indicated good repeatability of measurements. The cutting forces are measured by using tool dynamometer is the best technique available. As per analysis of forces, it has concluded that the cutting & feed forces are directly proportional to depth of cut & feed rate of tool.

VII. CONCLUSIONS

Differences between values obtained for cutting forces calculated based on theoretically accepted values and the experimental values. The analytically calculated forces be considered as reference values and shows the 29 % differences between the values studied for the dial indicator method, the highest error 33.75% and the lowest error 2.36%. When these results were compared to the theoretical analysis results, their error is less than 2.6%. It means that the experiments and the theoretical calculation have a good agreement. The tool force dynamometer is reliable as a measurement system. This system is an alternative method for the measurement of the forces that can be applied in a turning process.

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